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GEOGRAPHIC RESEARCH IN EASTERN IRAN

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GEOGRAPHIC RESEARCH IN EASTERN IRAN

II. ROUTES THROUGH THE LUT DESERT AND ITS ADJACENT AREAS

PREFACE

Now that this second and final volume of the report on my East Iranian Expedition is to appear, I should like to make reference to the foreword which served as an introduction to the first volume. It should be pointed out by way of enlarging on this foreword, that the author is aware of the unfortunate omissions which, because of more or less unknown areas, disturb the harmony of a research report. In particular, the observations on the vegetation may lead to rather modest results, since the collection of samples -- along with the rock specimens -- were destroyed in the confusion of the last war.

Neither I nor my tireless wife lacked the devotion or courage to carry through our appointed task of exploring the Lut Desert. If we were successful only in a small way, this should be attributed primarily to the fact that I was unable to accumulate the funds necessary for further research work. A relatively small amount would have enabled us to gain important knowledge in an area which to this day belongs among the few blank spots on our globe; but our hopes in this matter remained vain. It should also be pointed out for the reader's information that the results presented here were not achieved in easily accessible places, but are rather the product of hard and often bitter personal work.

However it should also be said that the Iranian government met my efforts with interest and understanding. I consider it my

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duty to thank them here at the end of my report, just as I did in my first report (Kampf um die Wueste [Struggle for the Desert]).

Klosterneuberg, December 1955

Professor Doctor Gustav Stratil-Sauer

Explanation of terms adopted from colloquial Persian for lack of a synonym in German:

Badgir -- a ventilator, similar in appearance to a chimney, which directs the wind into the house.

Band -- a dike thrown up to catch rain water on a gradual incline.

Djub -- an open irrigation ditch which carries water to a village or field.

Hauz -- a cistern, usually with a dome-shaped roof, in which rain water is collected.

Qanat -- an installation for underground collecting and conducting of ground water.

INTRODUCTION

If a writer wishes to know who has already explored the area which extends westward from the East Iranian Meridional Highway into the Lut Desert, his task is made relatively easy, since Gabriel (65) recently provided an excellent survey on this subject. This must be considered, in order that a distinction can be made between one's own work and that of others.

Aside from a scant few pieces of information, the western world gained its first knowledge of the geography of eastern Iran

from the expedition of Alexander. But even if we go along with the ideas of those who, like Bellew (9), would have us believe that the Qain city is the Artakoana which Alexander passed through, the Greek army still did not touch our area. The expedition of Craterus, on the other hand, certainly grazed the southern Lut in passing along the stretch between Nosratabad-Sipi and Fahredj, the same stretch which the modern highway follows; unfortunately, however, nothing remains from his reports. Antiochus the Great followed the same route a century later, but did not leave any interesting reports. "It was over 2,000 years later," writes Gabriel (65), "before the western world, through the Goldsmid mission (69), gained any exact knowledge of the desert road of Iran."

At the time of Christ Isidor V. Charax knew Nie, present-day Neh, as an important city. The notion of a Strabo and Ptomolaeus in this area was rather faulty, as is especially apparent from Tomaschek (157). We know that the knowledge of the area was increased by Arab geographers, but the West first learned about this almost 1,000 years later, and then only in part. We are particularly indebted to Schwarz (125) for opening up these sources to modern geography. The Lut was traversed repeatedly by Arab geographers. Istakhri called it the most dismal of all the deserts of Islam, and Muqadassi regarded it as an ocean in which one could cruise in all directions; the latter was correct in a limited sense only. We shall refer to this again.

I have already discussed the writings of Marco Polo, who crossed the area in his great travels (148). Almost 100 years ago Major published the travel report of Abd-er-razzak (1), who crossed the Lut (the "Desert of Kerman") and saw, so he claims, the ruins of a great walled city with 4 bazaars.

The first report made by a European on the route from Tabas (present-day Gulshan) to Birdjand came from Heinrich V. Poser, who in 1621 dared to make the extraordinary journey from Isfahan to India; on the return trip he followed our route from Khur to Birdjand. The Briton Coryat probably passed through this stretch a few years later. The fact that his report is lost is sorely felt by us, for he possessed an outstanding talent for observation; according to Gabriel he would probably be counted among the foremost explorers of Iran if he had been able to publish the account of his travels. The 2 British merchants Salbancke and Coverts on their way from Isfahan to India probably chose the route through Birdjand, it being the most popular one around 1600. Nevertheless when Wahl summarized the available information on Iran at the end of the eighteenth century, descriptions of the area were so few and at the same time so fantastic that one can hardly find one's way around in them (160).

In 1841 on his journey to Sistan, where he died, Forbes (50) passed through the mountainous terrain of Qainat, to the west of the present-day Meridional Highway, and thereby made known the area which Bunge traveled through 17 years later; very little other information is available on this area (23). Somewhat to the south of here our route to Khur was traveled by Buhse (22), whose chief accomplishment lies in being the first to traverse the Kavir. The great expedition of the Russian Geographical Society, which was made up of various specialists under the leadership of Khanikoff (93), is the most important one for our area. For the most part we followed in their footsteps from Basiran to Sar-i-chah and from there into the heart of the Lut in the vicinity of the Shur-Rud. We were also able to repeat the little side trip made

to Qal'eh-Seri by the geologist of the Russian expedition (Goebel), without however having to depend on his trip. In any case Khanikoff's work constitutes a valuable basis to which we shall frequently refer. In 1882 Stewart (136) traveled from Birdjand to Naiband and back; Baumgarten (8) followed the same route 12 years later. Slightly earlier that great explorer of Iran, Sykes (152), visited the village Zanagun on his first trip to Meshed; we studied this village on our fifth route.

A trip by Landor, who also traveled from Naiband to Birdjand, begins the twentieth century research; the earlier exploration trips in the Lut Desert by the English officer Galindo, except for a few pieces of information, have not been published (36).

The highly important trip by Sven Hedin (76, 77) in 1905-06 crossed our area on the Naiband -- Sar-i-Chah -- Neh line; it was very useful to us in the identification of rock samples and in keeping meteorological records. We also traveled along the stretch from Sar-i-Chah northward to Basiran, but in the opposite direction. In 1899 Sykes (150) crossed the Eastern Iranian Mountains and visited Qal'eh-Seri, mentioned above, and Neh. We often crossed the routes of this Briton who traveled so widely in Iran, and are indebted to his work for revealing much of great value (152).

In World War I Seiler (108) rode through the desert from Shah-Dat to Deh-Salm; because of the war conditions, however, he could not present any significant results of his observations along this route. We followed his route in places. Niedermayer in his trip through the Lut held further north than we; nevertheless we must refer frequently to his observations (106).

Two geologists of the Anglo-Iranian Oil Company, Jennings and Gray, worked in the vicinity of Naiband; their specimens were publicized by Douglas (40-42). We are indebted to the highly important explorations by Gabriel (60, 62) for knowledge of a number of entirely new facts; his second and third trips, in which he often crossed our routes, were carried out after ours. We followed his route in places between Shah-Dat and Deh-Salm in the Lut Desert. In addition geologists of the Anglo-Iranian Oil Company repeatedly traversed our area, but except for the summary by Clapp (30) no information has been published. The well-known trips by Rechinger also probably included Birdjand, but did not cross our western routes.

Thus our area has been traveled through many times, and important reports on it are available. Nevertheless most of our routes lead through land new to Geography, and that justifies our undertakings, which we sought to model -- unsuccessfully, of course -- after those of the old master, Hedin. We present here only those route surveys not covered by the cartographic work of the Britishers.

Since the geographical concept "Lut" is sometimes used in different senses, it is necessary to define its borders. As Hedin has already demonstrated (76), the Iranians used the word Lut to refer to a barren landscape bare of all vegetation and completely lacking in water. It is typical that Hedin first heard the word used in the area to the south of Gulshan (Tabas). It is true that the Great Kavir also has no vegetation and no potable water, but here the soft ground which characterizes the so-called "kavir subsoil" is more common than the "Lut type"; the latter first appears

south of Gulshan. The relatively short stretches of kavir within the Lut are referred to by the Iranians as "kavir," but here the term is quite properly subordinate to "Lut," for the kavir is surrounded on all sides by the Lut, the complete desert, waterless and without vegetation.

Nowadays the word Lut is also applied to areas in southeastern Iran where there are long stretches which are barren of vegetation in places. For example, the section of the Meridional Highway between Neh and Hurmuk (see Volume I, page 32 ff) runs through what the Iranians consider "Lut," although desert plants grow in the gullies along here. Also the stretch between Khur and Zanagun is called "Lut" by the local population, but only isolated spots deserve the name.

The Iranians apply the name Lut not so much to a geographical area in its entirety as to a phytogeographical type; in the process they make the term too all-inclusive and give an exaggeratedly harsh character to many landscapes. But how should it be otherwise with these highly fanciful people?

It is necessary to the geography of Iran to establish clearly what areas are to be understood by the word "Lut." To be sure, the desert belt of inner Iran extends southeastward from an area not far from the gates of Teheran, but I cannot accept Sykes' idea (150) that the Lut begins there, since Great Kavir has become the accepted name for this area. Nor should the Bahabad Desert be considered part of the Lut, for it is separated from the basins of the Lut by mountain ranges of imposing height. Hedin also makes a sharp distinction between these 2 names. We will define the Lut as that great southern basin bounded in the east

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by the East Iranian Mountains and in the west by a system of mountains extending from Duhak through Ravar to Shah-Dat and Bam. In the north this basin ends with the Duhak -- Kavir Desert -- Bijistand uplift; in the south, together with the Zangi-Ahmad Desert and the Narmanshir, it goes over into the southern Shah Savaran Mountains. Thus the rim of the Lut basin is constituted of important mountain ranges on all sides except the northern (Sketch No 1).

The northern Lut is separated from the middle Lut by the mountainous area between Garmab and Ateshan; nevertheless the water -- what part of it does not end in the smaller local basins -- runs off in the direction of the middle and southern Lut. The latter are also referred to as the Shah-Dat Basin.

I accepted this 3-way division earlier (146) and I believe I can hold to it. Gabriel (65) also adopted it recently.

ROUTE I. NEH TO AMBAR

(see Sketches 2-7)

A. From Neh to Deh-Salm

(a) Neh

The geographical situation of Neh is in many respects most noteworthy. Here ends the "peninsula" of civilization which, thanks to the abundance of water in the East Iranian Mountains, extends southward between the deserts. Between the Zabolistan Basin and the Lut Desert the East Iranian Mountains become narrower and lower. To the south of the Neh Basin begins the Lut, "the Nothingness," as the Iranians say. Here their farmland ends.

To the south begins the nomad grounds of the Baluchi. Zabolistan to the east-southeast is an oasis, thanks to the Helmand River and Hamun Lake. To be sure, agriculture is practiced again today in the Baluchi area around Sarhad and Bashakird, and was formerly practiced more extensively, as is apparent from the abandoned villages and watering places. Nevertheless nomadism is the leading economic form south of Neh. However today's modern technology has uncovered new watering places along the lines of travel and thereby brought about new settlements which practice agriculture.

To the south of Neh the summer heat areas begin. Many of the inhabitants have already been moved to abandon their homes because of the heat. The Iranians, who do not bear up well under excessively hot summers, have abandoned the area to the more tenacious Baluchi. The differences between the 2 peoples is made even deeper by the difference in religion, for the Baluchi are mostly Sunnites. Another noteworthy item concerning the climate is that the road leading south in Neh marks the snow boundary. It is true that we found snow in Neh in the winter of 1932-33, which was in general a year of heavy snowfall, but the local population declared that this was the first time this had happened in 20 years. South of Neh snow is unknown except in the mountains. The summer north wind blows here in these wide basins with a force unknown in the northern areas. It even uproots fruit trees. It actually blows for 4 months only, and is therefore called the 120 day wind -- correctly so, in this southern area, as distinct from many northern areas. In spite of the cooler air brought by these winds, the summers are so hot that the inhabitants prefer at that time to move 20 km further into the mountains. It is even possible to set up windmills in Neh. They are built facing north. Grain is

brought from Sistan. The basic tuff (Gest. Pr. [Gesteinsprobe -- Rock Sample] XXXVIII) in Neh can be broken and it is used to make mill stones.

In addition to these climatic, political, and economic characteristics, Neh is also noteworthy in its location with respect to traffic. On the road to the south the caravans -- whenever travel through the robber-infested nomad area was possible -- had few watering places at their disposal, and these were far between; therefore Neh became something of a trade center where caravans were reformed. Moreover the best route between east and west, i.e., between the provinces of Kerman and Zabolistan, is by way of Neh. Caravans can cross the southern basin of the Lut Desert only on the stretch through the Deh-Salm Oasis; and from here the best route to the Meridional Highway, as well as to Zabolistan is through Neh. Moreover the best route northwest to Gulshan is along the edge of the East Iranian Mountains, where water is abundant, through Naiband or Khur. It is indicative of the summer increase in heat that south of Neh travel, when it is not completely suspended, is possible only at night; this is true even of travel by modern motor vehicles, unless special precautions are taken.

Neh is conditioned by its situation in dangerous proximity to desert and nomadism. Its area, importance, and population have varied constantly, since traffic has often been interrupted for long periods during troubled times. The location is proving unfavorable today, for modern auto traffic passes 3 km to the east along the Meridional Highway.

Today Neh has at the most 2,000 inhabitants. Of its 400-odd houses many stand empty. The castle, which was erected on what appears to be an artificial hill, stands on the southern edge of town -- significantly, for the greatest danger always came from this direction. It faces on the Rud-i-Balkh, which contains water only part of the time, and is protected on all sides by a moat led off from the river. It was possible to keep this moat in a swampy condition even in the dry summer months by the process of draining into it all the city's sewage. The river also marks the southern boundary of the town; only the small suburb Bengiabad lies on both sides of the river. (Probably more correctly Bandiabad, from band meaning dike, so called because the Rud-i-Balkh was dammed here to improve the defenses of the castle.)

The bazaar is not concentrated in one place as in most cities, but divided among 3 places. This is probably an indication of how slowly the city grew; its first bazaar was laid out near the castle, the second along the main road leading north, and the third, which shows signs of planning, around an area suitable as a rest and trade center for camel caravans. The surrounding gardens and fields are irrigated by several qanats, in one of which warm water flows (22° C on 6 January, in a night when all standing water was covered with a thick sheet of ice). High winter temperatures in qanat water have also been reported from Ravar on the other side of the Lut (154). There are of course no palms in Neh as in Zabolistan, which is nearby, but also 600 m lower. The common fruits grow in the gardens in Neh; of these only the jujubes are particularly renowned. Nor is there anything outstanding among the field crops. Cotton growing is becoming more and more widespread. Dyeing with indigo is still practiced

in the bazaars, but in very small amounts compared to former days. There is but little rug weaving. Trade of course has declined sharply now that the important traffic bypasses the town. A certain amount of importance still attaches to the trade in wood from the "forest"; we shall learn more about this forest later (see below). Transportation is by camels, which are more intensively bred here in the old tradition; they are also used to transport the grain surplus from Zabolistan to the western areas of Iran. However it is apparent from the many windmills fallen to ruin north of the city that the grain trade must have declined sharply; of the 40 mills (there were 70 in Hedin's time!), only a few are still in operation. The relatively large number of cows in Neh is undoubtedly a consequence of the heavy milk production in nearby Zabolistan.

In Neh we were shown panned gold said to have been found near the Kuh-i-Diwar and Kuh-i-Dishe. One "mesqal" can be bought in the city at the price of one toman. 4.38 g = 15 M [mesqal]. (Here and hereafter the currency values are those of 1932.)

It is a tragedy of fate that this city, which once protected the east Iranian peasantry from the nomads, is today being conquered -- more or less peacefully to be sure -- by nomads, who find shelter during the winters in the numerous empty houses, and in the spring drive their herds out to the mountain pastures.

Following Isidor V. Charax' description of "Nie" as an important city, we have no word about the city until the time of the Arab geographers. The latter however have nothing of substance to say about it. The first information from modern times is provided by Khanikoff's expedition (93). Khanikoff gives the elevation of

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Neh as 1,141 m, whereas Hedin found it to be 1,196 m, and Gabriel 1,184 m; our figure was 1,195 m. Approaching from the robber-infested nomad grounds of the east, one finds the city a place of order. To begin with we shall describe the windmills. Khanikoff may have been right when he speculated that these windmills represent man's first use of wind power; this theory is based on the type of vane, which -- interestingly enough -- is unknown in nearby Zabolistan, as I have already pointed out (148). These mills do not operate with vaned wheels on the screw principle, but rather with wheels turning on a vertical axis, half covered, so that the wind caught in the funnel strikes the vane only during the time it is opposed to it. The type of windmill known to us as "Dutch" is, of course, much more efficient in its utilization of power than the Neh type; an analogy might be made with the difference in efficiency between a ship with a screw propellor and one with a paddle wheel.

Khanikoff's observations on thermal waters in qanats confirm ours: 26.3° C at a depth of 33.5 m and 14.5° C at a depth of 16.5 m (in March). The abundance of fish in qanat water is striking; these fish, 8 to 10 cm long, swim in thick swarms, and if one sticks a hand in they bump against it to the extent that one feels positively massaged. As to the statement that amethysts are to be found in Neh, we were able to learn nothing.

Neh has fallen off since Sven Hedin's visit there. Most notably, of the 200 camels there in his time, we found only 1/3 or 1/4, for the demand for them has almost ceased altogether because of the general motorization. Gabriel (62) also reports that the city has declined. Incidentally he occupied himself for the most

part with the ruins of a settlement on the summit of a steep cone-shaped hill on the Meridional Highway to the southeast of modern Neh. He does not agree with Sykes' theory (151) that these ruins are the remains of ancient Neh; according to him this once well-protected fortification, with its 100 small houses, its caves, and its 7 large cisterns, must have been a robber-baron castle. As a matter of fact in the popular tongue of today the place is called Qal'eh-Shah-Dozd, that is, Castle of the Robber Captain. Sykes states that he has seen no larger complex of ruins in eastern Iran, but in so saying he could not have been thinking of the ruins in Sistan or of the old city in Bam.

It was not possible to take our vehicle along the direct caravan route from Neh to Deh-Salm because of the narrow passages. We took a detour, crossing the caravan route in a half figure 8, going first north and then south. Since this route of ours can be followed on page H 40 F of the 1/4 inch map, I shall not describe it here.

(b) From Neh to the Mountain Pass

Leaving the furrowed, sediment-formed Kuh-i-Bagan Chain -- also known as Kuh-i-Neh -- on the left, we travel through a small, loamy semidesert strewn with small stone fragments and overgrown with stunted saltwort which serves as pasturage. We have to cross numerous heat cracks leading from the right and running in the direction of the Rud-i-Balkh. We arrive at an abandoned dry well, the Hauz-i-Nim-Farsakh; after 3 km, which is what the name means. (Farsakh, the older Parasange, is the distance which can be covered in one hour, that is, depending on local differences, 4 to 7 km.) After another 3 km we come to the Hauz-i-Yak-Farsakh, that is, the

One-Farsakh Well. From here we travel in the dry bed of the Rud-i-Balkh, 60 m wide and from one to 1 1/2 m deep. Indicative of how small its water flow must be is the fact that its pebbles are at most no larger than one's hand, and even in the bed itself steppe plants grow on little hummocks. Having left behind the gullies which run from the right from the dark eruptive-formed Kuh-Chashmeh, we come to the Hauz-i-Ibrahim; at this point, 8 km beyond Neh, the river bed abruptly becomes 20 m narrower and at the same time more meandering.

Bearing to the left, we are now headed directly toward the heavy gneiss-bearing conglomerates which make up the Kuh-i-Bagan Chain. We reach the top through a gorge which curves into the mountains, and from the pass (1,500 m) look out over the western slopes of the Kuh-i-Bagan, sprinkled with saltwort. Nearby the slopes appear to be well articulated, but in the distance -- probably another rock -- they appear to be disintegrated in bad-lands form, and the gradual slope from the well-defined ridge to the broad valley depression of Gaud-i-Neh is covered with rock slides. There are numerous white salt-gypsum efflorescences in the rock rubble. The valley itself, which is closed off on the west by the massif of the Kuh-i-Shah and its many spurs, is drained by one large and many smaller stream beds. Because of its many bushes it appears green, so that we understand why the local population refers to this semidesert as a "forest."

(c) From the Mountain Pass to the Neh -- Deh-Salm Caravan Route

Descending in a heat crack, on the higher spots of which saxaul grows, we come to a diverging chain of clay slate hills.

But as we descend into this broad sink the floor covering gradually changes from gravelly rock to loam, until finally the ground is covered over with riffled dunes and gray sand containing a great deal of mica. Here and there are smooth swept places with coarse, black, egg-sized clastics; they rise from the surrounding area like small islands. The firmer support indicates that these are the tops of a buried relief.

Vegetation becomes more common: tamarisk, zygophyllum, artemisia, saxaul. The bare, vegetation-free spots appear rarely. In the loamy areas, where wet places bear witness to good water supply, one can see saxaul bushes about one m apart growing as much as 2 m high and with branches from 10 to 15 cm in diameter. In the sand dune zone the saxaul bushes become somewhat lower and grow further apart; along the caravan route they average 75 cm in height and grow very far apart.

Large quantities of wood from this "forest" are transported by oxen from the nearby village of Chehar-Farsakh ("4-hour Travel," i.e., measured from Neh), and by camel from Neh. The nomads, whose black tents are to be seen frequently along here, use it to make charcoal. They have thrown up dams on the relatively steep slopes to catch rain water, so that the fields may be cultivated. Where there are gradual slopes in the loamy ground they have thrown up mounds in the shape of half-moons to create primitive water troughs for the cattle. We pitched camp XXI near the path in the "forest" of the Gaud-i-Neh at an elevation of 1,100 m.

Sven Hedin, who passed through the northern part of the Gaud-i-Neh on his way from Sar-i-Chah to Neh, described it as a semi-desert with scant vegetation. He encountered many nomads, who were

living there at that time (28 and 29 March) in greater numbers than in the cold of January. On the basis of his descriptions we can understand why our guide led us through this difficult terrain rather than along the caravan route through the Gudar-i-Chabisi and the Chabis Pass (Shah-Dat today). Hedin writes, "the rock is partially red-brown sandstone, partially massive white limestone. The vertical tablelands run from northwest to southeast, and since the valley we are following cuts diagonally through the rock, its course is extraordinarily devious; although we are on our way east, we are actually traveling in all 4 directions; some of the windings are only 2 m long" (76, page 151).

For a distance of almost 20 km to the NNE we were crossing the chain of the Neh Mountains over nonfossiliferous conglomerates containing a great deal of gneiss. We were not able to determine the attitude of bedding: even the survey we made under compass reading 20° in a slight deviation from the trend of the mountain chain (137, page 75) did not yield any indication of the nature of the bedding. Not until shortly before entrance into the valley depression did we measure schists dipping 70° to the west and striking almost north-south (10°).

(d) From the Caravan Route to Deh-Salm

The caravan route leads across the spurs of the Kuh-i-Shah. Our guide told us that the narrow passages were impassable for motor vehicles so we bypassed the mountains in a circle to the south. It was a difficult trip.

Soon leaving the dunes behind in our upward progress, we now find drifting sand only in protected places. On the other

hand, the rock barrens are now larger and made up of coarser clastics; these offer better support than the many salt efflorescences or the soft stone kavir. The sinks again contain loam and sand, but only scanty growths of saxaul, zygophyllum, and artemisia; we frequently fall through the stone kavir crust into the soft underlying salt layer. Insofar as possible we keep to the rock barrens until we reach a high point, a barren upland from which it is possible to view the broad sink we have just traversed between the Kuh-i-Shah, the Kuh-i-Bagan, and the Kuh-Estin (these mountains are called Kuh-i-Sind on the map). One can see clearly from there how it is overgrown with bushes in the north, but toward the south turns to clod and salt kavir and higher and higher dune formations. Here begins the great belt of dunes on the southeast rim of the Lut which Gabriel later described in more detail, and which he followed far to the south. We travel downstream in a dry river bed in the direction of the gradually flattening spurs of the Kuh-i-Shah, which still stand between us and Deh-Salm. The bed is about 30 m wide; at first it contains some saxaul, isolated desert gourds, and a great deal of saltwort; later it becomes sandy and bare of vegetation. To the right the land is powdered with white salt efflorescences which extend to the pediment of the mountains.

Moving up the slope, we plow through loose, clod kavir, powdered with salt and completely bare of vegetation; we cut diagonally through a broad vertical scarp zone with numerous veins of quartz, and beds of quartzite striking 10°, but also filled out with hardened sand and clay. The hard strata have been weathered to walls. Moving upstream in a new gully, we come upon granite and pegmatite with hornblende; a mica schist with

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vertical dip and north-south strike is bedded in between. The kavir formation is especially notable on the granite floor. Wide flats contain salt efflorescences.

A broad bed of greenstone (Rock Sample XL) leads us to the Chah-Rui height (1,150 m), which is the Deh-Salm watershed. The stream in which we descend contains in its sandy bed, among other things, artemisia and saxaul up to 2 m high; to the left is kavir soil. The quartzite, still running in beds, forms the 6-m high cut bank on the left; eventually the quartzite is replaced by banded, sandy phyllite (Rock Sample XLI) with 10° strike and vertical dip. Four km further there appears on the right a 10-m high cut bank of pegmatites, dike rocks, and quartzite striking in the same direction and dipping 60° to the west. Beyond this point the river bed, which is now 50 m wide, cuts into a mica schist striking 50°; it walls the bed in on both sides, 25 km from Deh-Salm the stream runs through an area of gradually flattening hills covered with rich growths of saxaul; 19 km from our goal it runs through higher hills made up of siliceous mica schists once again striking 10°. The salt is not so thick here as on the granite; the latter also begins to appear again. Vegetation in the form of desert plants no more than 50 cm high is still to be found but only along the edge of the dry bed, which is now 100 m wide. Eleven km from Deh-Salm the stream subdivides to pass an inselberg of dark eruptive. We are now moving toward the palms of Deh-Salm across an almost bare plain, where the scanty growths of weeds can be found only in the sinks, and across barrens with egg-size clastics.

The route from Neh to Deh-Salm connects 3 sinks separated by 2 mountain ranges. It would be profitable to compare the individual phenomena of these 3 sinks. Let us consider these 3 sinks, namely the Basin of Neh, the Gaudi-Neh, and the Basin of Deh-Salm, first from the point of view of vegetation. Near Neh, at an elevation of 1,200-1,400 m, we find good camel pasturage consisting of a thick growth of the usual desert plants. Because of the 120-day winds trees can grow here only if protected by fences, and aside from the modest orchards of the local inhabitants they do not exist any more. Farming in nonirrigated fields has not ceased altogether, but it plays an unimportant role.

The Gaudi-Neh, which we crossed at the only slightly lower elevation of 1,150-1,250 m, is characterized as to vegetation by the "forest" described above; further south this forest grows more and more sparse, becomes restricted to the valleys, and is finally reduced to patches. According to Gabriel's observations (60) the offshoots of this forest extend to the edge of the great sand dunes. The heights of the Kuh-i-Shah supply the sink with water and, apparently, insure the existence of the forest. It also waters the "steppe" which Sven Hedin (76) passed through to the north of us. The face of the Kuh-i-Shah falls steeply to the unimportant ridge, 100 to 300 m above the Gaud-i-Neh, which connects the Kuh-i-Shah with the Kuh-i-Chah-Rui. Since there are no water sources of importance here, the water from the Kuh-i-Shah sinks into the sand on its way south; that part which continues carries away the salt of the stream beds, but not of the surrounding area. Therefore there is no fertile ground for vegetation; on the contrary, we encounter kavir formations here. This "stone kavir" consists of a deflated floor with a more or less heavy layer of boulders over a

layer of salt or gypsum resembling powdered snow and mixed with rock residue left from chemical weathering. No doubt the forest also owes its existence to the lack of permanent settlements in the Gaud-i-Neh, which I believe is the result of the heat and the dust storms.

The Lut proper, bare of vegetation, begins at the pediment of the Kuh-i-Chah-Rui, and even earlier on a few bare heights, as we call the bald ridges in rolling stretches; along the final stretches, at a height of 850 to 950 m, the Lut becomes increasingly dominant. In places in the Gaud-i-Neh the nomads could raise barley and millet in fields dammed up to catch the water (though not all year round); but here only a few isolated plants are able to withstand the wind, heat, and dryness.

The disposition of the sand fields is also interesting. The north wind has piled up sand dunes in the Neh Basin, most notably in the area of Khunik. They are located on the southern edge of the basin and are an example of the law on the disposition of sand zones first recognized by Sven Hedin; they are formed by the north wind where the sink rises and slows the air movements. As for the dunes near Hoshare at the entrance of the basin (which are grown over with vegetation), I was not able to determine whether these were formed by the north wind or the south wind.

According to Gabriel (62) the great dunes on the eastern edge of the Lut were formed by the south wind, whereas the sand zones in the adjoining Gaud-i-Neh show clearly the effects of the north wind; however it is not probable that they were formed by the north wind, for in the Lut Desert the latter is usually accompanied by conditions of good visibility, whereas the dust and

sand wind -- the Bad-i-Khassif or Bad-i-Radd -- comes from the south. It is therefore more likely that the south wind transports the sand from the dunes zone and deposits it in the gap between the mountain ranges where the Gaud-i-Neh narrows, and at the same time is deflected in a more westerly direction. Similarly in the area of Deh-Salm the effect of the north wind is apparent, whereas the sand sheets of the mountains can be traced to the working of the south wind. As in the case of the Kuregi-Navar Basin (148, page 68), difficulties arise if one attempts to consider the deposition of the sand between the Lut and Sistan from a single point of view, for both the south wind and the north wind work their effects here. We shall refer to this again.

Hedin's observations (16) are available on the eastern chain and the mountains of Neh. He found vertical sandstones and limestones here. A specimen was classified by Asklund (3) as grayish-red, layered fossil limestone. At the place of this discovery Hedin measured dip 75° north 40° east, which accords with our description of strike 40° and dip 75° to the northeast. The next specimen was from a bed of dense, grayish-white, very crumbly limestone with dip 87° south 30° west (i.e., almost perpendicular with 30° strike). A yellowish-gray conglomerate, but well stratified, limestone with variously colored fragments dipped 70° south 20° west (i.e., strike 20° and dip 70° to the southwest). Another of Hedin's specimens from a bed dipping 60° north 20° west (i.e., strike 160° and dip 60° to the northwest) was described by Dietrich as a contact metamorphosed limestone. Southwest of Neh Hedin (7) discovered a dark andesite tuff with a rusty crust.

Thus where there is a steep dip the strike deviates only slightly (30° at the most) from the 10° we measured on the descent into the Gaud.

The second chain which runs southward from the Kuh-i-Shah and plays out not far beyond the Kuh-i-Chah-Rui, was also crossed by Gabriel (62); he noted here granite with veins of pegmatite. To the north of there begins augite porphyry covered with a semi-red protective rind. Gabriel also mentions a dull green porphyritic andesite at a point outside our route. However Sedlacek (128) who analyzed Gabriel's specimens, does not say anything about the attitude of bedding.

Passing through this low chain we repeatedly had to cross beds of quartzite which were raised in the form of little walls or beds of softer rock weathered to furrows; these can be followed for great distances along a 10° line of strike. The mica schist and a narrow zone of greenstone also strike north-south. On the west side quartzite and pegmatite beds appear on the surface striking in the same direction. Not until 10 km beyond the ridge does the mica schist strike northwest-southeast with a perpendicular dip.

The mountains of Neh trend 20° to 30°, but the western chain begins earlier to run meridionally. As soon as we began the descent into the basin we measured clay slates striking 10°. The mountains of Neh do not begin to range south until we reach the Kuh-i-Palangan, whereas west of the Gaud-i-Neh this direction becomes predominant at the Kuh-i-Shah. These facts which are connected with the Hercynian trends observed on Route V near Isfandiyan, cannot be definitively treated until additional observations have been made and evaluated.

Stahl (132) describes the granites south of Kuhbanan on the other side of the Lut as Archean. Pilgrim (113) places the great diorite intrusion of the Kuh-i-Panj northeast of Saidabad in the Lower Eocene. Furon (55) describes the granite of Meshed as an old base with 2 separate folds. However Bonnard estimates its age as between the Upper Jurassic and the Lower Cretaceous. Vredenburg (158) places the granite south of Zabidan in the Tertiary; I was not able to determine the age of the granite I found at Nosratabad (148).

The granites of the Kuh-i-Chah-Rui are probably overlapped by the strata complexes of the Kuh-i-Shah, as will become apparent. We shall encounter granodiorites near Deh-Salm.

(e) The Oasis of Deh-Salm

The Deh-Salm Oasis is, as it were, the outer harbor of Neh on the ocean of the Lut. Its situation is fixed once and for all by the fact that its surrounding mountains make it possible to collect a relatively large amount of qanat water. But it is also determined by the course of the caravan route from Neh to Shah-Dat, which, to be sure, does not run as the crow flies, but which is nevertheless the most direct route, since one must go 50 or 60 km north from Shah-Dat in order to cross the Namakzar by way of the Gudar-i-Barut (the Powder Keg), or, if the kavir is dry, by way of Bagh-i-Asad (Garden of the Lions). From this point the caravan route turns somewhat southwards from direct east because of the precipitous declivities of the "Lut cities" (see Route III), the Gusheh (Highway) Pass, which leads from the recent sedimentary basin deposits to a higher level, and finally, because of the pass between the Kuh-Rigi (Sand Mountain) and the Kuh-i-Simurghi

(Mountain of the 30 Birds), 14 km before Deh-Salm. Since this is the last watering place along a stretch of about 200 km it has always had a special importance in this southernmost transversal route of the desert. The traffic to the north is of little importance; the route, which is in good shape by and large, is traveled a little each year after the rainy season. The route to the south, known to us through the Arab geographers, is not traveled today.

The Gaud-i-Dehbala, "The Broad Plain" in which Deh-Salm is situated, is covered with coarse gravel and near the center of the basin run through with broad strips of kavir. Only sparse saxaul bushes and various halophytes grow here, mostly on deflation hills up to 2 m high. The area is bounded in the north by the heights of the Kuh-i-Shah and its spurs (the real source of the water); in the west it is bounded by the peaks of the Kuh-Rigi, and in the south by the smallish inselbergs on the uplift between the Kuh-i-Simurghi and Kamerash, and by the front dunes of the great ocean of sand along the eastern-edge of the Lut. In the east it is bounded by the mountain ridges between the Kuh-i-Shah and Chah-Rui which we crossed on the way here (see page 19). This enclosed basin, which like so many others in the Lut has no outlet, is traversed by the Rud-i-Savar or Shur-Rud and by many gullies which bear water only part of the time; these empty into the Namakzar, the northern low point of the sink. (The Namakzar near Deh-Salm is to be distinguished from the one mentioned above, which is in the heart of the Lut.) These gullies often spill over into the plain, destroying their banks, so that in many cases they have no erosion rim. The primary denuding force is the wind. The elevation of the oasis is 865 m.

Little information is available on the climate of Deh-Salm. According to the inhabitants snowfalls are extremely rare; the one at the end of December 1932 was the first since the winter of 1913-14. Light ice formation during the night is a frequent occurrence, however. On 8 and 9 September we observed lows of 0 and 1° C respectively. The weather was clear and the temperature rose rapidly, reaching the maximum of 20° C at 1300 hours; it then fell so slowly that at 1900 hours it was still 10-11° C. Apparently cold air blasts such as we experienced on the northern route through the Lut (Route V) often reach Deh-Salm from the Siberian-Turanian area and cause the temperature breaks feared by the inhabitants because of the date harvest.

The sand storms begin in the spring. To be sure, there are few days during the winter when the wind is still, and the Bad-i-Khassif (Dirt Wind), a south wind which transports sand from the dunes belt of the Lut, blows frequently. But the genuine sand storms, which rage with an unheard of violence, do not begin until the warm weather arrives. It is because of them that the caravan traffic ends with the winter months, for the heat does not become unbearable until May.

We arrived at Deh-Salm in great haste at 1730 hours on 27 March in the midst of a great sandstorm and measured the temperature at 23° C, more or less the same temperature observed throughout the trip. Scattered rain drops from low-hanging nimbus clouds indicated that the rain was evaporating before reaching the ground. At 1800 hours the wind shifted to the west and diminished somewhat in force but persisted throughout the night; as the sky began to clear up and the air became free of dust, the temperature fell to a low of 4° C.

Nothing is known concerning the summer temperatures in Deh-Salm. Most of the inhabitants leave the oasis in the early spring and go with their herds into the Kuh-i-Shah and remain there until fall. The few who remain behind with a few chickens and at most one sheep per household (the latter is also sent to the mountains in May) complain of an absolutely frightful heat during which many people die of "contraction of the heart and shortness of breath" -- i.e., of malaria. According to Gabriel's observations on the western edge of the Lut and ours around Nosratabad, the temperatures may hover around 45° C at noon; and lie between 15 and 25° C at night. The north wind mitigates the heat somewhat. There are no badgirs in Deh-Salm, but most of the houses are so constructed that it is possible to let the north wind pass freely through the house if it is dust-free and not too strong. However the north wind is not so completely predominant here as in many areas of eastern Iran; fearful storms often come from the south, bringing such heat, dust, and sand as to make life a hell on earth. The inhabitants also report that in the summer sudden whirlwinds often bury the oasis under sand.

According to observations by Gabriel the high in the autumn months may be between 25 and 30° C, but it cools off greatly at night. Gabriel measured the humidity at 8% at the end of October; there is no other information on humidity.

A clue to the average yearly temperature can be found in the temperature of the qanat water. This was 23° C on 7 January (!). It could not be thermal water, because according to the inhabitants it becomes warmer in the summer. In other places along the edge of the desert qanat water was found to be 20° C and higher.

The sand ripples indicate that the prevailing winds are from the northwest, but the worst sand storms apparently come from the south and southeast, bringing sand and dust from the sand dune belt of the Lut. Precipitation can occur from January to March and on rare occasions in December or at the beginning of April. Thunder storms are common in the mountains. Judging by the amount of rock debris in the gullies it appears that the precipitation must be extremely heavy at times, but from the sand transportation it also appears that sometimes there is no rain at all for years at a time.

Thus Deh-Salm has an arid continental climate, all the more so because of the openness of the basin to the north wind, which blows along the slopes of the Kuh-i-Shah, and the south wind, which blows across a relatively open uplift in the terrain; the unhindered shifts in the wind direction effect the temperature variations described above. It is well known that the continental climate is mitigated by the existence of high mountains in the vicinity, but the Kuh-i-Shah, which is only 49 km away, appears to have little influence here.

Here on the edge of the inhabitable world 80 to 100 people live in 30 to 40 houses during the winter and about 5 or 10% that many during the 6 months of summer. But it was not always so. According to the description by Mukadasis (157) the place known to medieval geographers as Pharca -- the location of which can be placed even today by the clay shards to the south of the oasis -- must have had several thousand inhabitants. But even in Mukadasis' time the city was in ruins. In the myths of present-day Deh-Salm the oasis is represented as having had 10 qanats and 3,000 camels.

This may be attributed in part to the Oriental penchant for exaggeration, but the many abandoned installations bear witness to the fact that irrigation -- and therefore agriculture -- was once practiced much more extensively. The most important trade route to southeastern Iran, the route from Zabolistan to Kerman, passed almost exclusively by way of Deh-Salm in those days.

The decline of Deh-Salm, which apparently took place during the last decade, is attributed by the native population to the 1912 Baluchi invasion which afflicted the oasis sorely -- and Neh, too, incidentally. But considering its location on the edge of civilization in a desert which even today is a "Pirate Sea," Deh-Salm surely must have withstood many attacks in the past, regaining its strength from the life blood of commercial traffic. Of course I have been told that the decline is the result of opium addiction and the lethargy of the people. No doubt many a person here has sold his last date tree in order to be able to eat opium -- in its milder form, or to smoke it in a form which is usually deadly. However we were able to see in eastern Iran that the poorest of the poor usually fall prey to this addiction once they have passed beyond all hope and can find their last happiness only in narcosis. It would seem in order, then, to examine the economy of the place in order to discover the causes of the decline.

The staple of the oasis is the date. The plantings, laid out in the immediate surroundings, are obviously old, and many have died for lack of irrigation or care. The dates are eaten fresh from the tree, pickled and cooked, or fried in fat. Just as the peasant in the areas on the edge of the desert divides up

his wheat or millet as his staple food for that year, so does each family here attempt to insure its minimal existence with the date crop. To be sure, it is not all his: as a leasehold village, Deh-Salm must hand over 2/5 of its harvest -- 1/5 for the ground and 1/5 for the water -- to the prince of Birdjand, who as leaseholder is responsible for, or at least interested in, the maintenance of the qanats. Moreover, many inhabitants have pawned or sold their date trees. In any case, if the harvest is a good one, the village has about 100 to 150 mans of dates left to sell after deductions for personal use and contractual obligations. A "heavy man" equals 3.4 kg, so that the total is around 340 to 410 kg. Because of the climatic conditions, however, the size of the harvest varies radically. If the average yield is estimated at 170 to 210 kg [sic], the 1932 harvest was exactly enough for personal use and nothing was left over for sale. Since the dates of Deh-Salm are inferior to those of Shah-Dat, the rather low price of 5 to 7 Pfg [Pfennig -- German penny] per kilogram is understandable, although the isolated location of the oasis should increase the price. Unfortunately citrus trees from the other side of the Lut have refused to grow in Deh-Salm, but apparently not because of the climatic conditions: the inhabitants say that citrus fruits were formerly cultivated in Deh-Salm, but that they cannot stand the somewhat salty qanat water. Probably the abandoned qanats once produced good water, but with their destruction citrus cultivation ceased.

In and around the date trees cotton is the chief crop; it is worked up by the men with hand spindles and by the women with spinning wheels. Unless there is a good crop there is only enough for personal use and the taxation, so that normally nothing is

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left over for sale. In many areas of eastern Iran cotton constitutes, as it were, the small change of the national economy, i.e., it is sold to cover the small household expenses. In Deh-Salm this is usually not true. As for wheat and vegetable cultivation, it is very minor and hardly sufficient to cover individual needs. Barley was formerly cultivated as a second crop, the straw being sold with profit to passing caravans; today the barley yield is insignificant.

Deh-Salm possesses 4 donkeys, 10 camels, 70 to 90 sheep, and a few chickens. The sumpters are frequently used to transport wood to Neh from the Kuh-i-Shah area or from the "forest" (see page 16). About 30 pfg is paid for 100 kg. This work is undertaken especially whenever the men of Deh-Salm are not able to hire themselves out with their camels to transport goods through the desert. Today there is little to be transported, for the caravans are entrusted only with goods of low value, the goods of higher value being given over to auto transport. On occasion a replacement for a man or animal is sought in Deh-Salm if one falls by the wayside along the desert route.

Ten percent of the camels -- i.e., at the present time, one camel per year -- can be sold. The people of Deh-Salm are experienced breeders.

They cannot afford to slaughter their sheep. They need the milk, fat, and wool for their own use, but are able to sell a little cheese to the caravans. About 20% of the sheep are sold each year bringing a profit of about 30 marks.

The total average yearly income for the oasis can be summarized as follows:

	M /Marks/ (Value of 1933)
Sale of Dates	12.00
Sale of Barley	5.00
Sale of Sheep	30.00
Sale of Eggs and Cheese	3.00
Sale of One Camel	80.00
Sale of Wood (3 camel loads in 3 months)	54.00
Transport through the Lut (5 camels)	200.00
Assistance to and shelter for caravans	30.00
Total	414.00

Taking this in round figures as 400 marks it works out to 4 marks per year per capita.

With this the oasis must defray the cost of importing wheat, sugar, meat, and oil, not to mention such luxuries as tea, tobacco, or opium -- the latter costs 29 pfg per mesqel! Throughout eastern Iran the young man must save up money before courting a woman, but because of the shortage of money in Deh-Salm -- where there is monogamy, of course -- the parents-in-law must be content with a guarantee that they will be provided with food for life and with evidence of properties worth from 30 to 300 marks, e.g., a house, date palms, sheep, or rugs. Throughout the duration of the marriage the right of usufruct remains with the family, and in case of separation goes over to the wife's family. Because of the lack of capital the families of Deh-Salm usually marry among themselves and as a result family ties are complex. The inbreeding has led

to a striking resemblance among the members of the community. Bodily resistance is low and there are signs of degeneration. If a woman has 5 children she can raise at most 2 or 3 of them, and of those who grow up, few live beyond the age of 50.

It is a common practice here to buy and sell shares in the ownership of a camel, since these are among the most valuable assets. The loss of an animal is a catastrophic blow to a family. We were able to observe this in 2 cases, for the Baluchi had stolen some animals 2 months before our arrival.

Thus these people are caught in a frightful poverty without even being able to see the nature of their difficulties. Emigration following upon loss of all property is becoming more and more common. As is apparent from the above table, their primary source of income is still caravan transport, and one can imagine how great their income must have been in the days when they had 3,000 camels of their own to fulfill the requirements of heavy commercial traffic. But today it is no longer profitable for them to invest in camels. The great price drop, which reduced camels to 1/5 their former value, brought about a surplus in sumpter animals -- all the result of the reorientation caused by motorization in the Orient. I have already discussed this in detail elsewhere (138).

In Deh-Salm the poorest of the poor for the most part have already passed beyond all hope, and they fall victim sooner or later to temptation in order to free their hopeless lives -- for a few sweet hours at least -- from the burden of the present, thereby attaining a reward never to be had in reality.

Gabriel, who visited Deh-Salm a few months after us, passes judgment rather harshly: "the people of Deh-Salm behave savagely and importunately. Here, as in so many other places in Iran's deserts, the repugnant characteristics of the people, in particular their tendency to think only of their own advantage, can only be accounted for by the disease and hardness of the natural environment" (60, page 226).

Thus an oasis sinks into oblivion, a victim of a fateful development in the general geographical reorientation, after having produced a race which for centuries stood up under the most difficult struggle on the edge of possible human habitation. But perhaps our automobile, which was regarded as a great wonder in Deh-Salm, was only the first swallow. Perhaps technology will overcome the few remaining difficulties and transform the old caravan route into a modern automobile highway. Then Deh-Salm will come to the fore again, to be sure under different circumstances. Now as before it remains the last watering place along the shortest route through the Lut between Sistan and Kerman. Without Deh-Salm a highway through the Lut is not possible -- but of course without the highway Deh-Salm is not possible.

B. The Inselbergs of the Eastern Lut

Once the heights to the east of Deh-Salm have been crossed one is in the Lut Basin proper. On the way over we crossed the last of the great basins which lie between the mountains of Neh, Kuh-Estin, etc and the Kuh-i-Shah and its spurs. Now, however, we enter the great depression proper. On its eastern edge it is characterized by inselbergs; in the many smaller basins and pans are the usual kavir formations. In order to gain information about

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these inselbergs we visited the most important ones, the Kuh-i-Surkh (Purple Mountain), Kuh-Abdullahi, and Kuh-Bakhtu (Bactrian Mountain); because of trouble with the differential we were not able to reach the Kuh-i-Murgab (Bird-Water Mountain).

(a) To the Kuh-i-Surkh

The first inselberg, the Kuh-i-Siah (Black Mountain), appears just 5 km from Deh-Salm; it is constituted of granodiorite run through with numerous amphibolites and pegmatite veins (Rock Sample XLIII). Although it towers 260 m above the surrounding area, drift sand has been deposited all the way to the top, and everywhere the effects of corrosion are apparent. It is surprising that up here, where one would expect the effects of chemical weathering to be slight in comparison with the mechanical, the feldspar is kaolinizing. As it crumbles it mixes with the transported material to form a sort of "white snow powder"; in the process, miniature kavirs are forming in small hollows.

This observation which I was able to make elsewhere, surprised me very much. It is generally assumed that in dry areas kaolin and other silicate clay minerals cannot form because of the "Al weathering" (i.e., with a preponderance of Al), as opposed to the "Sial weathering" in temperate zones (i.e., with Si and Al). Moreover as Schwarzbach (126) has demonstrated, the arid climates lack the humus acid which binds the colloidal SiO_2. The highly desilicified Mediterranian terra rossa shows that the humus decomposes too rapidly in arid regions; clay minerals do not form, but rather alhydrates. Even though Harrasowitz (73) points out that in the literature the process of podsol formation has frequently been mistaken for kaolinization, I stand by my

observation -- all the more so since Kaiser (90) describes in detail the considerable kaolinization in the Namib Desert. Rittmann (119) recently observed the same phenomenon in Egypt.

Since the amphibolites and dike rocks are much more resistant than the surrounding material it is understandable that they form the crest of the Kuh-i-Siah. Not far to the west are the peaks of the Kuh-Rigi (Sand Mountain), about 180 m higher; to a much greater extent they are covered with sand which is transported by the wind from the southeast; from the ridge to the valleys they bear sand sheets. In the south are small hills with convex slopes, for the most part no more than 50 to 100 m higher than the plain. Only the 2 Kuh-i-Simurghi (Mountains of the 30 Birds) have an elevation approximately equal to the Kuh-i-Siah.

We broke camp on 9 January at 1200 hours and set out along the caravan route to Shah-Dat, crossing the dry bed of the Shur-Rud after a gentle descent. The temperature was 13° C. Saltwort grows in big clumps on deflation hills; a few attain to a height of 2 m. On both sides of the Shur-Rud are cloddy kavir soil and salt efflorescences. Clayey kavir clods lie in the deeper depressions in the midst of powdered salt. But after 3 km we are traveling on a firm rock floor, covered with hard, sharply angular clastics of green dike rock up to the size of a child's head. A desert plant known here as rams [See Note] grows on a number of flat islands of drift sand. The characteristic coloring of the hill on left, as well as the sink which follows, is provided by greenstone. The grandiorite mentioned above begins to show "Kanzel" formations in the upper part of the peaks, which rise to a height of about 60 m. Five hundred meters to the left the sharp-ridged Kuh-Shukumbar

rises 100 m above the flat; we were not able to determine whether its strikingly light color is attributable to a dike rock. The Kuh-Rigi-Pain (Lower Sand Mountain), like its mate, which we have already made reference to, bears sand transported from the southeast as high as its ridge. The small erosion channels we have to cross have salt efflorescences on their cut banks, which are 10 to 30 cm high and exposed to the southeast; there is no salt on the slip-off bank to the right. This phenomenon is probably connected with the direction of the wind, especially since we later shall come upon strong evidences of the north wind.

([Note] I was not able to determine the botanical name of this plant since the specimens we brought back have been destroyed by fire. Rams usually appears in sandy soil; it is similar in appearance to the usual saltwort. We noted one growth about 40 cm high.)

After 14 km we arrive at a broad bare saddle between Kanzelbildungen on the right and hills on the left. The sharp wind and the transported sand indicate that it is a powerful vent hole. At the Kuh-Rigi-Bala (Upper Sand Mountain) we observe limestone with approximate north-south strike between sheets of eruptive dipping 30° to the west. The path descends into a broad, shallow valley depression strewn with smooth fine gravel, very slightly furrowed, and almost entirely barren of vegetation; from there it climbs to a small sand kavir, crosses a shallow trench lined with dunes, crosses the barely apparent SSW running wadi of the Rud-i-Savar, and proceeds up the regularly furrowed, gruss-strewn slope, along which extremely isolated rams stand in small, sand-filled erosion channels. Descending gently, still on a grandiorite floor,

the path leads through bare sand between established stone markers, crosses low dunes strewn with gravel, and arrives at a north-south running chain of hills, the Shakas-Bala-Sard (Upper Cold Hill Land). At the same time the color of the ground changes, so that without investigating we know that we have left the granodiorite and entered upon a new rock. We cross a small patch of kavir soil, then of loose sand; after 30.5 km we reach a high point, whence we proceed across a dark reddish gray floor with gravel in which the path is better defined. We move toward a mountain where the path turns more to the west-southwest while we proceed directly toward the peak of the Kuh-i-Surkh under compass reading 50°. We are now traveling across a gently sinking flat with small dune deposits, completely free of vegetation. The wind must be extremely strong here, for even the gravel is formed into small, sharply ridged dunes.

After 40 km the rock floor begins to change continually. Frequently, narrow bands run through it in a north-south direction; 12 km before Kuh-i-Surkh we go somewhat out of our way into the hills to the left in order to take Rock Sample XLVII, a dark eruptive. The dunes and ripple marks run 90°, indicating the effect of the north wind. In spite of the continuing sink of the terrain, the dunes formations cease 9 km from the Kuh-i-Surkh and give way to a gravelly crust. Nearer the inselberg we again encounter gullies with kavir formations on their slopes and sand in the beds, indicative of the paucity of water. We move across the pediment of the mountain and pitch Camp XXIV at the foot of its abrupt northeast face. Not far away are the graves of 3 camel drivers slain by the Baluchi. They are marked with stones laid out in the life-size forms of the slain.

The Kuh-i-Surkh, with its one main and 2 secondary peaks, is a characteristic landmark of the eastern Lut in the vicinity of Deh-Salm. It rises abruptly to a height of about 1,210 m, i.e., almost 400 m above the surrounding area; its slope line, first concave, then convex, is remarkably free of talus. The NNE side bears an especially great amount of transported sand, but here too there is no waste mantle. It is built up of massive, dark gray, only slightly folded limestone rocks (Rock Sample XLVIII) for the most part in 3-m beds. Their jointing strikes north-south or 30° or perpendicular thereto. The extremely hard rock is covered with small karren and a black encrustation. A few grooves cut deeply into the mountain, but the many erosion channels which extend upward from the pediment hardly scratch the surface (Sketch 4).

The summit of the mountain affords a broad view over the desert. To the northeast for a distance of about one km drifting sand covers the pediment; the latter slopes gently for about 6 km to the hills, which, interspersed with many basins and salt kavir formations, stretch into the vicinity of the Kuh-Abdullahi.

To the south (170°) the pediment is bounded after 5 to 8 km by a sandy wadi. It collects the numerous streams of the mountain, the slopes of which bear salt efflorescences wherever there is no gravel. Here there is relatively little drift sand; it is restricted for the most part to small islands. The nearby hills, which are almost buried in sand and rubble, exhibit numerous smallish peaks; the Deh-Salm guide was able to name only 2, the Kuh-i-Dishalal and the Tshinge-Sifala. In the erosion channels grow a little artemisia, saltwort, and tamarisk, the latter up to 1/2 m

high. In the winter a little water can be found in the eastern gorge. The path from the Kuh-Abdullahi passes by the Kuh-i-Surkh and joins the Deh-Salm -- Shah-Dat caravan route at the point where it rises out of the sedimentary basin deposits to the higher level (see Route III).

An entirely new ground structure is clearly apparent this side of the caravan route; narrow meridional bands run through the desert, indicative of a different formation about which we shall learn more later.

Once again we are struck by the mysterious distribution of the sand. This sand was certainly transported here by the south wind, and it is deposited on the southern slopes of a number of mountains. But on the Surkh-Kuh it appears on the north and north-east, which would lead one to assume that it collects on the lee-ward side. The sand fields to the east of the mountain remain un-explained; nor can I explain the sand which occurs in strips, usually isolated, 1 to 2 m long and only a few centimeters wide.

The most lasting impression made by this stretch is that here for the first time the completely barren desert is dominant: as far as the eye can see there is no trace of vegetation.

Others traveled the route to Kuh-i-Surkh before us, namely, the "Desert Foxes" of World War I under First Lieutenant Sailer; but they, being occupied with the enemy, had no time for geo-graphical observations. Gabriel followed parts of our route on his way from Shah-Dat to Deh-Salm, but at night; therefore there are no precedents to our report.

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The Kuh-i-Siah apparently owes its existence to the harder amphibolites and dike rocks; the surrounding granodiorite has been worn down to a rolling plain. The Kuh-i-Surkh, which apparently derives its name from a phenomenon similar to our alpenglow, is constituted of extraordinarily resistant limestone and can only be accounted for as a denudation residual. Gray described a similar limestone on the west side of the Lut as a rudistid of the Upper Cretaceous. The question of the age of the Kuh-i-Surkh must be left open, for the ammonite we found there could not be more accurately classified. The eastern slope of the mountain rises abruptly from a pediment several kilometers wide; the junction of the limestone to the mica schist base could not be determined.

One is impressed, particularly on the stretch between the Gaud-i-Neh and Deh-Salm, by the intensive weathering of the granite and its feldspar. The ground in the granite zone is almost without exception "soft"; the wheels sank in several centimeters; under the thin crust, kaolinized granite with salt and rock residue has formed a "stone kavir," as our guide called it. To the west of Deh-Salm the granite and granodiorite floor becomes notably more firm, for here chemical weathering cannot operate so intensively. We should not ascribe this phenomenon so much to change in the nature of the rock -- although pegmatite plays a greater role on the east side of the oasis than on the west -- as to hydration which is certainly less operative in the basins of the Lut proper than in the heights east of Deh-Salm. We believe this assumption to be justified, for we were able to make the same observation in all places, and Mortenson (104) and Passarge (109) have also demonstrated in other areas that the extent of chemical weathering depends to a great degree on the amount of precipitation.

Concerning the geological structure, we were able to determine that eruptives were intruded in the granite body -- apparently in meridional fissures. The greenstone reported in eastern Iran by Furon (56) and Clapp (30) also appears in meridional beds.

(b) To Kuh-Abdullahi

Having returned to the Deh-Selm -- Shah-Dat caravan route, we set out in the direction of the second characteristic inselberg, the Kuh-Abdullahi. We travel through a gently rolling area and then through degraded hills covered with sand and small clastics, or rather a smooth plain with a few ripples from which the lighter material has been blown away, leaving a gravel residue. Before us on the right lies the salt kavir of the Namakzar. Five kilometers beyond the path we cross a small gravel-covered pan without drainage and after a slight climb arrive in buried hills. The quartzite and basic eruptive here is heavily coated with desert varnish. Isolated haulms up to 3 cm high grow out of the stony floor, and stunted desert plants in the few sandy erosion gullies. After crossing a larger stream bed grown over with saltwort, we pass over 3 small chains of hills, the quartzite beds of which are covered with carmine-red or black desert varnish. The Kuh-Abdullahi now lies before us on the left. Because it is better driving we hold to the right, traveling over the rolling land of a degradation plain through which cut the outcrops of the 50 and 100° striking beds of greenish, sharply folded, somewhat exfoliated limestone; eruptives are interbedded in the limestone. There are numerous diagonal rock bars, often in the form of slates or clay shales. Usually, however, only the constantly changing coloration

of the desert pavement discloses the regular change in the nature of the rock. As in the trip to the Surkh-Kuh we are now traveling over radically folded residual mountains.

The landscape changes now as we pass out of the hills and rock bars and move straight up a wadi with salt efflorescences on its flat slopes. Strips of desert plants grow in small rain gullies. From this point, more or less in the direct line between Deh-Salm and the Kuh-Abdullahi, the Rigi Mountains are visible to the southeast, separated from us by kavir and the Namakzar. We move toward the Kuh-Abdullahi over a barren, stony plain, the green and dark red coloration of which is reminiscent of the surface on the other side of Deh-Salm. A few desert plants grow in the deeper spots. We are now climbing, moving over a dark gravelly crust through which a loam-colored subsurface frequently breaks. To the left a small chain of hills, the Dag-i-Madkhan, rises out of a broad plain, the shallow pans of which are blown over with sand. After crossing a number of kavir stretches and an area with thick growths of 40-cm saltwort between salt efflorescences, we climb a small hill and look down into a broad, clayey basin. It is divided by 3 low hills isolated from the Abdullahi and ranging off to the south. As we descend into the basin we encounter saltwort and "Holzdorn" in the deeper spots, but the higher levels are bare. We now move uphill in the direction of the mountain, crossing small hills with kavir slopes; we cross erosion runs, which become more and more frequent as we approach the mountain. Bushes grow in abundance in one of the stream beds, and even a katur tree (Astralagus gummifer), the first tree we have seen since the dates of Deh-Salm. One could even dig a well here, but the water is too salty for the camels. They graze freely in the area but return home after a few days for water.

Another 2 km and we have reached the Kuh-Abdullahi. It rises 100 to 200 m above the surrounding area, which is 1,070-1,080 m high. Its most characteristic feature is the tilted table which falls steeply southward to the piedmont. It is made up of hard gray limestone in the overlying beds. The base is of hard arkose sandstone and the ridge in the east is covered with dark gray limestone rocks with an easterly 20° dip, similar to those of the Kuh-i-Surkh. In all probability we are dealing here with east-west faults en echelon. At least this may be assumed, since the easterly dipping key horizon may be traced in the 3 hills mentioned above as they gradually sink away. The 10-m broad alluvial cone of the Abdullahi blends quickly into the basin floor.

(c) To the Kuh-Bakhtu

In order to reach the Kuh-Bakhtu we pass around the Abdullahi on the east and then travel northwest between it and the northern peaks of the Kuh-Siah. Broad bare spots along here are coated with a black desert varnish, but lighter spots lacking this varnish have an abundance of desert plants, even in the higher areas, which are usually barren of vegetation. Game is relatively abundant in this area, and we observe bustards -- the so-called "dukhtai" -- and hares, as well as the tracks of gazelles. To the northwest stretches a broad, flat, undrained basin with white salt kavir. It is bounded in the north-northeast by the Kuh-i-Do-Sar (Mountain of the 2 Peaks). We then drive down the Rud-Chah-Chile, a 50-m broad wadi which contains water in places; tamarisk clumps up to 2 m high grow here and there in the bed. The following chart shows the changes in the rock.

Km from Abdullahi	Type of Rock	Rock Specimen No	Line of Strike	Dip : 1
11	gray limestone	--	--	--
11	dark eruptive of the nature of basalt	L	--	--
11	tuff in lump form	LI	--	--
11	east-west fault traces	--	--	--
11	folds and nappes of alpine type	--	north-south, approximately	--
12	yellowish arkosic sandstone	--	90	30 north
14	argillaceous sandstone	--	60	70 north
17	gray sandstone	--	10	40 east
18	brown argillaceous sandstone	--	10	30 east
19	argillaceous sandstone	--	?	-southeast
19	argillaceous sandstone	--	north-south, approximately	30 west
19 1/2	?	--	?	-east
20	micaceous, argillaceous sandstones, somewhat exfoliated	--	mostly 10°	various

It is possible to follow the Chah-Chile for almost 20 km. Kavir formation is common on its edges and along the flood plain. Salt efflorescences 200-300 m wide extend like snow drifts to the pediment of the accompanying hills or mountains. In certain conglomerates, the deposition of which has not been explained, we observe an horizon of gypsum stalactites such as Walter or Passarge have described.

After 15 km the river, which has become 100 m wide, dries up on argillaceous sandstone rocks, so that the heavy growths of tamarisk cease. It is amazing to see the bed cut 2 to 4 m deep -- up to 10 m after we have gone 20 km. Scoured out areas and sharp edges indicate the effects of lateral erosion. The great extent of downcutting is probably attributable to flash floods; judging by the growth of bushes, the last one must have been 3 or 4 years ago.

After 22 km we leave the wadi and strike out across a gravelly tableland, moving down a gentle incline toward the Bakhtu. We cut diagonally across a small gully and from the twenty-fifth kilometer on move across a broadly rolling hilly area covered with rock fragments up to the size of a child's head. In the sinks there are a few halophytes and frequent patches of cloddy clay kavir ringed with salt. Later we again move across a level plain covered for the most part with coarse gravel. At the thirty-sixth kilometer mark broader gullies indicate the nearness of the massif. We halt at the thirty-ninth kilometer mark under compass reading 30° to the center of the massif and pitch camp between 2 streams which are rapidly cutting deep into the gravel.

(d) The Kuh-Bakhtu

The Kuh-Bakhtu constitutes a small range of inselbergs dissected into numerous peaks surrounding the main peak. We expended a great deal of effort attempting to work up a cartographic basis for the morphological description; but it developed -- surprisingly -- that the 150 sightings could not be used because of disturbances which caused deviation of the magnetic needle. Sightings taken on

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a second climb on 22 March proved on analysis to be misleading and worthless. So it is apparent that the deviation was not caused by a magnetic tremor, as we at first assumed; rather the cause must be sought in the mountain itself. Two examples will illustrate the magnitude of this deviation. The sighting from the east peak to the west peak resulted in 125° but the reverse was 102° plus 180! Sightings of the Kuh-i-Shah, which is about 70 km away, were taken from both peaks; according to sightings with the plane table the results should have been 276° and 279° respectively; instead of this we got the impossibly divergent values 281° and 267°! Only the plane table records and those sightings mapped on the spot have any claim to correctness. Future special investigations of the Kuh-Bakhtu should determine whether the disappointment in the cartographic survey is to be balanced by the joy of having discovered a magnetic anomaly.

We undertook our first ascent of the Kuh-Bakhtu from Camp 26 (880 m high) on 12 January. Of the 2 streams which extend southeastward from the massif we chose to follow the eastern one. It is incised almost 20 m into the gravel so that in places it has already reached the bedrock. It contains some water here. The closer we come to the leeward side of the mountains, the more drift sand we encounter. We reach a point where sand has drifted into the stream: beyond this point the bed is incised only a few meters deep, but begins to run in short, sharp crooks and meanders, which is especially surprising in the relatively steeply graded stretches. On the western slope larger dunes have been accumulated by the southeast wind. Following the right hand stream, we discover that it has robbed the western main stream of its upper course. The gravelly ridge which today separates the upper course

of the western bed from its former upper catchment area indicates that the piracy took place on a higher level (see Sketch 5).

Wherever the debris-filled stream encounters sand dunes it goes into incised meanders. The old gravel indicates that the eastern drainage captured the western on a higher level.

We climb up a steep talus slope to a secondary peak (1,235 m). It is separated by a scarp zone from the main ridge which rises in a steep wall almost 100 m high. Here we find melaphyne (Rock Sample LII), numerous light-colored veins with pyrite crystals (Rock Sample LIII) running parallel to the scarp zone, and in the scarp zone proper a porphyritic formation (Rock Sample LIV). In camp we had broken a sample of light eruptive with crystals (Rock Sample LV). Insofar as we could observe the Bakhtu appears to be constituted of eruptives and their tuffs.

When we visited the Bakhtu a second time from 21 to 23 March we pitched Camp 47 on the northwest side at an elevation of 865 m.

We climb in a gorge running 160° along bedding and jointing striking in the same direction. The melaphyres show bright schlieren and red intercalations, especially where there is honeycomb weathering. Layers of tuff appear frequently in the melaphyre, a phenomenon which, morphologically, usually appears in softer forms. At an elevation of 1,115 m the gradient becomes less steep in the more resistant tuffs. We reach a secondary ridge with a peak (1,130 m) and from there climb, once more very steeply, in another stream bed. A heavy iron-bearing bed of quartzite strikes 160° in the floor of the bed. It is possible that strata such as this are responsible for the strong magnetic anomaly mentioned above.

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The bedrock is often polished smooth, especially on the peaks. We reach the eastern peak at an elevation of 1,480 m, 600 m above the pediment of the mountain. From here the uneven sculpture of the Bakhtu is apparent. Whereas the southeast of the massif is dissected into numerous broad valley depressions and peaks, the northwest wall of the ridge falls directly to the piedmont with but few stages and breaks. In their upper courses the streams run mostly in the direction of jointing, i.e., 70° or 250° and 160° and 340°. On the middle and lower levels other laws are operative. The drift sand is accumulated mostly in the south, indicating the work of the south wind and the effect of the protection afforded by the valleys and peaks. Even on the summit the glassy, friable melaphyres bespeak the corrosive effects of the wind.

From here to the middle peak -- where the sighting on one occasion was 147° and on another 123° (!) -- leads a small 1,240 m high col; further down are 2 rock pinnacles. The ridge, which swings somewhat to the south, ends with the western peak, 1,320 m high. Here the dissection of the massif is clearly visible. Along the tectonic lines already mentioned valleys have been reamed out, which together with their tributary gullies form mountains and hills. On the basis of observations made on the first ascent, and also on the basis of the gravel deposits (which we shall encounter again on the descent), it appears that most of the forms were already here before the gravel was deposited. So far as we could tell, more gravel is being scoured out at the present time and sand is being deposited in areas protected from the wind. The inselbergs which ring the Bakhtu, particularly in the north, may have been separated from the main massif under these

processes, but doubtless long before the gravel deposition (see Sketch 6).

For long stretches in the northwest the main crest falls directly to the gravel-strewn plain. The latter is cut deeply by a river which collects the discharges of the gullies streaming down the mountain. The river has many bifurcations and is bounded by inselbergs.

We descend in a stream bed between the 2 crags of the middle peak; the going is difficult, down steps as much as 10 m high over which water falls during the rainy season. The bed runs in a 70° line. At an elevation of 1,050 m the gradient becomes gentler and the slope less steep (see Sketch 7). At Point 2 the stream changes it course to almost due north while the jointing, clearly visible, continues as before. The stream bed is incised into the bedrock in which veins strike 160°. Soon however the bed is filled with gravel and the stream enters the alluvial fan. Drift sand covers the slopes; where it is blown into the bed the river begins to meander, as on the south slope, in a clearly recognizable terrace. Beyond Point 3, where the direction changes again, the stream is incised 30 m in the gravel. In spite of the meandering the gradient is steeper beyond Point 3 than it was where the course was almost straight, which is contrary to all expectation. The question as to whether a break in the profile was created before the gravel was deposited or whether the drift sand has created a dam upstream will be discussed below. That a river filled with rock debris should begin to meander as soon as it encounters drift sand opens up new points of view in the meander problem. Before Point 6, where the cut bank is no longer covered

with sand, it can be seen that the gravel is made up of such diverse elements as fanglomerate, loess, fine layered sands, and drift sand containing clastics, all without any recognizable unity or any apparent key horizon. It is apparent however that the younger gravel is embedded in the older. Whereas the older hills, which rise 50 m above the river bed, are being built up, the younger gravel terrace is being deposited in the bed and then merges to the level of the alluvial cone. The same older gravel can be seen on the slope of the Bakhtu across from Point 9. It is separated by meandering streams from the massif and constitutes a small ridge running parallel to it.

Returning from Point 6 diagonally across the alluvial cone to camp we encounter gravel in considerable thicknesses, as indicated in the following table.

Point	Interval in m	Width of the Stream	Depth of the Stream
7	140	3	1
8	105	30	10
9	370	5	1
10	150	5	1
11	60	3	1
12	160	2	2
13	165	20	5 (coming from the eastern saddle)
14	90	10	3
15	185	15	10

Between points 9 and 12 there are only smaller streams to be crossed on the alluvial cone; here on the slope of the Bakhtu the

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water runs off in numerous small streams which do not flow into any main stream. Further down, where the downcutting eases, most of the larger streams also subdivide into smaller ones.

I have already attempted elsewhere (137) to describe an encounter with the lofty Kuh-Bakhtu, the most impressive of the inselbergs of the eastern Lut. Situated near the rim of the desert, which in places appears as an abrupt break, it rises alone with its spurs to an imposing height, visible far and wide as a landmark for the caravan guide seeking the way northeastward to the watering place of Ambar, 20 km from here. Therefore as I have indicated elsewhere (144), I cannot accept Tomaschek's interpretation of the name as meaning "Thunder Mountain," especially since thunder is relatively uncommon here, or at any rate by no means characteristic. Rather this is the "Bactrian Mountain," i.e., the mountain which showed the way to Bactria to the caravans from Kerman and Shah-Dat.

Khanikoff brought back the first information about it, the "Mihibakhtou, couronne de rochers." However we learn from his report only that 3 natural basins there accumulate water for long periods and that traces of life are to be found in the form of jerboas, beetles, and tarantulas. To this account we can add vultures, bustards, hares, and a beautiful steinbock.

Geologically the Bakhtu is a range constituted of melaphyre and its tuffs, cut by crevices striking approximately east-west (70°), and intensively dissected by valley erosion. Alpite and iron-bearing beds as well as pyrite frequently appear striking in the same direction or at right angles thereto. In the foothills a light eruptive is found.

The Bakhtu area turned out to be particularly valuable for morphological observations. In the first place, there are here 2 series of gravel of different ages; we shall discuss this after we have discussed analogous cases and considered the applicable literature. We should like to state here however that the present-day alluvial cone had a predecessor which produced fanglomerates of greater thickness. Because of the intervening erosion these have remained only in part. The younger gravels do not lie over the older here as is usual in such gravel fans; rather, according to our observations, the younger gravels are embedded in the older ones. This means that except for isolated remains along the edge of the mountains the older, larger alluvial cone was washed away and its last remaining broad heights filled out by the newly-formed cone. At the present time the stream beds are being scoured out and the alluvial cone washed away. Of course it is possible that in this process younger gravel was deposited in places on top of the older, but we did not observe any such cases on the Bakhtu.

The genesis of this phenomenon is substantiated by a case of stream capture on the southeast side. This capture took place in the stage after the old gravel deposition, when the downcutting began. Only thereby could remains of the higher level, which show the old course of the valley, have survived. In the same order as on the other side of the Bakhtu, the old gravel deposition, downcutting, and the new gravel deposition followed one after the other. To be sure, the younger and older gravels do not demonstrate any systematically different habits, but because of the alternating beds of fanglomerates, loess, drift sand, etc, they are so distinct from each other that one is led inescapably to

the conclusion that during each of the 2 periods which we tentatively call the "younger" and the "older" gravelling, there must have been a considerable differentiation between scour and transportation; this was probably due in part to climatic fluctuations. At the present time the alluvial cone of the Bakhtu area is once again in a period of scour. The vertical erosion has cut into the bedrock only in places. Further away from the foot of the mountain it has not even reached the bedrock in most places.

Valley forming is particularly interesting in the vegetation-free rock floors. Like that of the fold mountains north of Zahidan (148) it is largely determined in the beginning by the jointing. If the latter does not deviate too much from the strike of the slope it prescribes the course of the valley until the stream gathers enough erosion potential in its upper channel to enable it to pursue a course according to laws of its own.

The 2 corresponding cases of the meander phenomenon bear witness to the transformation of a stream upon its entering drift sand. These meanders cease as soon as the stream has passed through the sand zone. The meander problem posed by our observations is difficult because I have not been able to find a clear-cut coincidence of the phenomenon. These meanders in drift sand occur only in the upper channel of the stream (see Sketches 5 and 7). They are incised meanders: in places we could not see out over the bank. Evidently they developed when sand was blown into a previously formed valley course. This hypothesis is substantiated by observation of a small, somewhat sandy trough with clear-cut valley form which leads into the dunes. It clearly has an antecedent character. The original valley course was gradually

filled in with sand. The valley meanders -- so their forms indicate -- also frequently become blown over with sand and in places are even completely choked. Thus we may well assume that when the stream contains water it must frequently excavate a new bed. This means that meanders are newly formed -- or reformed -- each time the bed contains water. Thus one must deal in each case with freshly formed meanders.

These young incised meanders must have originated in a single cycle rather than 2 cycles. Instead of beginning at a higher level and gradually downcutting, as in the usual process, these meanders undoubtedly were formed immediately with the impact of the water.

The numerous theories on the origin of meanders were only recently summarized, so that it would be superfluous for us to go into detail. In any case, these theories could not be applied here, where dunes sand is obviously solely responsible for the formation. This type of genesis is all the more surprising considering that we have known since Gilbert's time that meanders do not appear in streams with an abundance of gravel; and the streams of the Kuh-Bakhtu have as much rock debris as other temporary water courses.

In attempting to explain this phenomenon we should bear in mind that water always seeks the course of least resistance: in dunes sand it finds this course in meanders. At first it may seem a contradiction in terms to say that a meandering -- and therefore longer -- valley course offers less resistance than a direct one. And yet Kaufmann in his discussion of the "Rhythmic Phenomena of the Earth's Surface" has opened our eyes to such possibilities.

Two media in movement -- water and sand in our case -- tend to order themselves so that friction will consume the least possible energy. These conditions are fulfilled in the course of a stream when a rhythmic alternation tosses the water first against the right bank, then against the left. In this manner the torrent is apparently minimally retarded, sand and water are separated out to the optimum, and the maximum energy is retained: this course thereby involves the least expenditure of energy /See Note/. One may object that such a theory of rhythmic phenomena is difficult to prove satisfactorily, but nevertheless there is much to be said for this explanation.

(/Note/ After the completion of this Vari-Typed edition appeared the work of C. Troll, "Concerning the Age and Formation of Valley Meanders" (Erdkunde /Geography/, No 4, 1954). This work confirms our hypothesis in many respects. "The meanders are not inherited river meanders" (page 298). "Their formation takes place under conditions of a definite relationship between water load, gradient, sediment load, form of the river bed, and grain size of the sediments" (page 399). However our example shows that under certain conditions the type of rock -- dunes sand in our case -- is by itself able to bring about meander formation.)

As for the second phenomenon, the abnormal steepening of the gradient in the meander sections, apparently the sudden diminution of the current on entering the dunes sand causes the stream to deposit much of the transported debris. This deposition levels the gradient considerably: in order to attain the normal profile again there must be a subsequent steepening. Thus dunes in the valley course change the normal profile insofar as there is a

leveling of the gradient above and a steepening below. This explains the exception to the rule: a stream on entering dunes, deposits so much material that it becomes relatively free of debris and is able to form meanders.

The Kuh-Bakhtu can also contribute to the question of pediment formation. It was extraordinarily impressive to note that many streams had cut down to the bedrock. The table which shows the width of the streams crossing the alluvial cone also indicates the varying masses of the forms. It will be noted therein that the drainage on alluvial cones does not -- as some authors assume -- "fall through" the easily eroded fanglomerate to the solid rock, i.e., to the pediment. Rather the nature of the long profile is prescribed by the force of the current and the amount of debris it transports. As is apparent from the table, the downcutting and lateral development are only indirectly dependent on each other, since these streams, being poor in water, are not superior in either breadth or depth as they rush down the alluvial cone with more or less equal gradient. There is no parallelism between the 2 factors.

The presence of bedrock in some of the stream beds shows that there is a pediment here. It was probably formed for the most part before the "older" deposition, since residue of the latter lies on top of it; but it was undoubtedly reformed together with the old gravels when the latter were scoured out prior to the formation of the young gravel.

In presenting a summary of Route I we should point out that later observations will contribute substantially. Baier (5, 6) was the first to point out that the old masses noted in the sinks of Anarek and Nain are strongly metamorphosed and sharply folded

complexes of strata. The peneplain there veneers residuals of crystalline schists, but also veneers the light limestone of the Upper Cretaceous which overlaps the schists. Baier proved the existence of a completely Alpine structure, even under the basins filled in the Miocene.

Without wanting to get ahead of our story we might describe a striking similarity to these facts here in the eastern part of the Lut. Doubtless we are dealing here with the remnants of an Alpine type mountain range trending for the most part north-south. Mica schists and clay slates are the representatives of this meridional formation (which must have had a predecessor); in the heart of these mountains appear granites and granodiorites. It is possible that they could be traced as far as Nosratabad-Sipi, where, according to Clapp (30), a coarse-grained granite forms the core of a north-south anticline interspersed with numerous beds of basic rock -- exactly the sort we found around Deh-Salm.

An additional orogeny included the sandstone and limestone of the Upper Cretaceous and Lower Tertiary, while at the same time important extrusions took place on the ocean floor. Finally, the area was again transsected by east-west faults, as the en echelon faults of the Kuh-Abdullahi show especially well.

The process of degradation, extending over all the rocks and mountain folds has brought about an erosional surface out of which rise the inselbergs. Apparently they owe their existence to the resistance of the rock, insofar as they were not tectonically formed.

(e) From the Kuh-Bakhtu to Ambar

We intended to go from the Bakhtu to the next inselberg complex on the edge of the Lut, the Kuh-i-Murghab. Since our camp lay between the 2 deeply incised streams, it was necessary to go back 2 km to the southeast in order to go around the Bakhtu at a point where the streams could be crossed. We encountered broad barren areas with egg-sized stones; the scanty vegetation was restricted to the deeper water channels. Because of an unfortunate automobile breakdown we had to give up all further plans and attempt to reach the nearest human settlement, Sar-i-Chah (Fountain Source), 100 km away.

At first we attempted to find the Shah-Dat -- Sar-i-Chah camel path -- where driving would be easier. We drove along a shallow stream and then across a gently rolling plain with various kavir basins and isolated growths of halophytes. We came upon a camel path leading from the left which our Deh-Salm guide unfortunately took to be the one we were looking for; but it ended at 2 wells in an erosion channel at the edge of a hill land. The wells contained about 7 m of silty saltwater.

At this point we had left the basin the Lut proper. The hilly area which with its numerous rounded peaks bounds the plain here, is of Alpine structure. We observed eruptives (Rock Sample LVI), pink, dark-green, and light gray tuffs, sandy slates striking 30°, sharply folded clay slates, phyllite and other rocks. In general the beds appear to be overturned to the west. The hills, which rise almost 100 m above the plain, are transected by many shallow troughs often running at 20° to 30°, for the most part along the line of strike. The slopes are very "soft," i.e., they

consist of salt and gypsum veneered by a thin pavement containing clastics up to the size of an egg. The peaks are paved with a firmer deflated surface. Surprisingly there is relatively abundant vegetation consisting of tamarisk, saxaul, and various types of halophytes.

We now moved directly toward the Migh-Ambar (Peak at the Well), a rock pinnacle which rises as a clearly visible landmark above the hills. We were supposed to find the caravan route there, but actually reached it earlier. We moved downstream in a 60-m broad river bed, left it when it became swampy, and then held more to the north, passing over dark gruss with a broad kavir on the left.

It had already occurred to us that these hills, which the Iranians call Shakasta (the shattered), are united by a common level. This impression becomes stronger as we move along the path, since the capping plane, now clearly apparent, joins the hills with their truncated peaks independently of the complicated subsurface structure. Here again we follow a stream; it contains -- interestingly -- rock terraces about 5 m high, and in the bed even the solid rock is visible. Especially noteworthy is a quartzite bed which strikes east-west, confirming the tectonic direction we have already established. We now encounter numerous salt kavir formations; even the ground in the stream bed is frequently white -- an exception to the rule, since elsewhere the erosion runs are free of precipitated salt. Patches of halophytes extend into the kavir.

After climbing about 50 m we reach a second level of peneplanation on which there are not so many peaks, but in their place

kavir areas. We move toward a green spot -- the well of Ambar. In the vicinity of Ambar grow tamarisk, saxaul, and desert plants; ligneous plants grow on small denudation hills, and rushes at the water edges. Ambar, the last watering place on the route through the Lut, is an important rest center for caravans. It also serves as a watering place for the grazing animals, which are driven here from the villages of Sar-i-Chah. We meet a solitary shepherd among the grazing sheep and goats. He is waiting for his camels, which scatter throughout the area and return after 5 days for water. Near the unusually warm well we observe hares and gazelles and the shepherd tells us that there are also wolves, foxes, jackals, and snakes in the area. According to this shepherd the south wind prevails here; he states that on some occasions the north wind has brought snow, which, to be sure, melts immediately.

We now travel to Birdjand via Karimabad; since we traveled this route again later, the observations made this time will be discussed together with the next route.

As we recapitulate important points of Route I it should be borne in mind that these points will be enlarged on by the material from the following routes.

The eastern part of the middle Lut is a basin, which is itself broken up into numerous small and large basins. Out of these basins rise a number of inselbergs. The whole constitutes the remains of a residual range of fold mountains of Alpine structure, the axis of which runs mostly north-south; this range is characterized by granite extrusions. The marine character is evidenced by the limestone embedded in the extensive volcanic effusions.

These facts have their analogies in the observations made by Baier (5, 6) in the western inner Iranian basins. Likewise eruptions in the neighboring areas were demonstrated by Vredenburg (158), Hedin (76) and Asklund (3), Furon (55), and Clapp (30).

The orogenic movements, which lasted from the beginning of the Cretaceous to the end of the Tertiary, did not end with this formation, for the latter was subsequently dissected by faults striking for the most part east-west. Moreover this formation must have had its predecessors.

As in the depressions of Anarek and Nain, the residual mountains in the eastern Lut are veneered by a pendulous degradation plain.

The discovery of 2 distinct gravel series is important. These series accord well with the observations -- already published (148) -- made near Birdjand.

Particularly important are the unusual intensity of the chemical weathering, the distinctive types of kavir formation (the salt, sand, loam, and clay kavir), and finally the boundary marking the end of vegetation in the Lut.

Significant in the field of economic geography are the summer evacuations in the fringe areas and the traces of agriculture without irrigation at elevations as low as 1,100 m.

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ROUTE II. FROM BIRDJAND TO KARIMABAD AND BACK

(see Sketches 8 and 9)

A. From Birdjand to Majan

(a) To the Pass at the Kuh-i-Rich

The way from Birdjand to Majan follows the highway to Khusp as far as Shamsabad; we shall discuss this highway later in context. At Shamsabad the path turns across the Bakaran Mountain Chain, which bounds the Birdjand valley depression on the south and separates it from the numerous villages of the Majan area. At first the path leads in a gradual ascent across the piedmont plain toward the gently sloping alluvial cone built by the River Shuragan, which enters the Birdjand valley depression at this point. We have to cross an interconnecting network of shallow erosion channels. Not far from the valley mouth is a water mill of the Oriental type so often described. The abundance of water here on the margin of the mountains is evidenced by the qanat conduit which follows our path, by the villages along the foot of the slope, and by a complete system of irrigation ditches by means of which broad stretches of the alluvial cone, which is overgrown with scanty saltwort and covered with pebbles, have been transformed into fields.

We now move across the heavily dissected alluvial cone into the valley of the Shuragan; we leave behind on our left a chain of foothills of chloride slates, apparently a fault en echelon to the great valley depression -- which is itself probably a graben. Having passed a few farms, a dam, and a number of fields, we arrive at Kelateh-Dehnou-Rikat, with 300 inhabitants the largest

village in the valley. Having moved southward up the valley to the first tributary on the left we come upon the first member of the rock series, an outcrop of chloride slate striking east-west and dipping 30° to the north. The broadened, funnel-shaped valley mouth is roomy and supplied with enough water for cultivation. A djub has been led on to the broad, stony stream on the right to carry off water. To the left irrigation ditches and a qanat supply water for terraced fields with the usual crops; in the vicinity of the settlement are gardens with pomegranates, grapes, and mulberry trees. The local pomegranate and mulberry jams enjoy an excellent renown.

The valley depression has 3 terraces -- though not throughout. Up the valley as far as the half-way point they are distinct; thereafter they are hard to trace. They lie about 20, 50, and 120 m, respectively, above the valley floor. They end at the valley mouth, a matter we shall discuss later (Route V). The frequent occurrence of earthquakes in Birdjand and Khusp, and especially in the Shuragan valley depression itself, indicates that deformational movements have not yet ceased here. The populace complains of the intensity of the many tremors and of their destructiveness.

Near the end of the valley mouth an ancient fort stands on the lowest terrace, evidence of the importance of the pass. Here we find sharply dipping chloride-rich coarse conglomerates (Rock Sample LXXII) under great strain. They are unconformably overlain by beds of calcareous sandstone (Rock Sample LXXIII), clearly demonstrating the double folding of the mountain chain. Apparently the conglomerates are bedded on top of the chloride

slates mentioned above, since most of the constituents are from the latter. Later we find flatter conglomerates striking 70° and becoming finer and yellower in the overlying layers; still later they appear in the form of an anticline, under the crest of which lies the village of Gubigan. The tiny place with its chloride-green houses is situated on the lower gravel terrace, from which the amply irrigated fields sink in steps to the valley. The population here is insured an additional income from wood transport to Birdjand.

From this point on, the stream bed, which contains water only in the winter, has steep banks and is incised 5 m deep. We move along it to the hamlet of Kelateh-Mudvat-Hadji-Beg. It consists of 2 houses and 2 families who live on the fruits of the fields and gardens. They also weave mats from cut reeds. The blunted pyramid of the Kuh-i-Rich, which has been visible along our entire course, stands here as a characteristic landmark. The local inhabitants know many sagas about the mountain connected with Rustam and other heroes of the Shah-Nameh. Possibly the name of the mountain is related to the name Aridj, son of Feridua. It is more likely, however, that a pre-Iranian name survives here in this "holy mountain"; I have already discussed this (Volume I, page 44). It is amazing to find pre-Islamic legends still alive here; for example, the local people know that the Kuh-i-Rich was formerly used as a laying out place for the dead, a monumental "Tower of Silence."

We were told that a rider in relief sculpture could be seen on the rock face of the Kuh-i-Rich and therefore decided to make a short detour up the mountain under the guidance of Yussuf, the

second of the 2 inhabitants of the hamlet; the other happened at the time to be on the way to Birdjand with a load of wood. The third terrace to which we now climb, is very large here and has a garden with numerous huts in which inhabitants of Khusp seek refuge from the summer heat. The terrace is transected by numerous small gulches which begin at the foot of the mountain; they contain tamarisk. Although its value as firewood is slight, it is collected and transported to Birdjand. After 2 km we reach the 2 houses of Batjik. The soft brown sandstone rocks on which the hamlet is situated strike 90° and, especially at the foot of the mountain, dip sharply; the light colored eruptives (Rock Sample LXXI) of the Kuh-i-Rich, rich in hornblende, rise abruptly. We were not able to determine the relation of the sandstone bedding to the eruptives, but the pointed pyramid form must be attributed in large measure to the resistance differentiation between the 2 types of rock.

After 3 km we arrive at a pass 250 m above the starting point, i.e., at an elevation of 2,120 m. It does not afford the expected view of a westerly continuation of the mountain range, but rather one of the transected plain of Khusp, broken by a few steep, inselberg-like cones. Apparently the Bakaran Chain is bounded in the west by a fault. The plain is furrowed by numerous streams and covered on the gentle slopes with broad salt efflorescences. The only settlement is the small village of Kharduzd (straw thief), about 4 km away. The plain is divided in 2 by the Barunda, its highest double peak, about 8 km to the west. Climbing steeply in the direction of the north face of the Kuh-i-Rich in a boulder-strewn furrow we look down into a defile in which a sharply graded rill is incised. The north face of the mountain exhibits

much honeycomb weathering. Inhabitants of the surrounding area also live in the defile in the hot weeks; it is a shady place rankly overgrown with dog roses. As it turned out the guide could not find the relief sculpture; but the inhabitants of Khusp assured me that it really exists. Perhaps the guide did not want to disclose its location to me. For my part I was hardly recovered from a severe illness and could not find the strength to undertake a second climb by myself.

Only a kilometer beyond Mudvat-Hadji-Beg the valley narrows to a canyon, in which we find outcrops of chloride slates, phyllites, numerous mica schists, but also the eruptives of the Kuh-i-Rich. At a fork in the river, where the valley again widens, lies a farm with orchards and fields. The numerous springs here have even conjured forth a meadow, a rarity here in the east. Further along we note lime in the chloride slates, broad, sharply dipping beds of phyllite striking 100 to 120°, and mica schists striking in the same direction. Toward the end, the valley becomes very steep and contains a great deal of pebbles of the Kuh-i-Rich eruptive; despite the elevation, the vegetation is sparse with saltwort predominant. Of course in April and May there will be a much greater variety. Climbing over coarse conglomerates and sandy slates (Rock Sample LXX), we reach the pass, 2,050 m high, still 400 m beneath the summit of the Kuh-i-Rich. The watershed has obviously been pushed back in recent times. One can see how the crest line of the pass swings to the south, especially near the Kuh-i-Rich. The overturned beds on the south slope of the Kuh-i-Rich show, as already reported, that this is the ridge of a range of Alpine type. This impression becomes stronger on the descent.

(b) From the Pass to Majan

The descent southward is less steep and we encounter softer forms, which is to be expected in view of the steepness on the northern side and the retreat of the watershed resulting from the more intensive erosion of the northern drainage. The rocks and the attitude of bedding change frequently; it is impossible to establish a basis for a special description, for the hired caravan guides insist on pushing ahead. The almost complete lack of vegetation at the pass is probably to be attributed chiefly to the sharp wind which we encountered as a regular thing in this vent hole. A little further down however saltwort and tamarisk appear. Descending in the broad floor of a valley, we encounter "greenstones," a phyllite bed with 20° strike, and later brown rocks similar to mica schists. The valley cuts slowly down, cuts out "Kanzeln," and narrows to a gorge where the outcrop consists of chloride slates which alternate constantly with dike rock (Rock Sample LXXVI: classification undetermined), and later merges to massive limestone. The pebbles are of the Kuh-i-Rich eruptives, but the latter were not observed outcropping south of the pass. Another 2 km along the sinuous river bed clay slates appear, and, still later, the brown rocks similar to mica schists. They are sharply folded and strike east-west for the most part. They are overthrust by very flat pressed fault breccia (Rock Sample LXXIII).

The path now leads along the right bank of the river bed, which lies 15 m deeper. We observe the characteristic tamarisk; it grows ever thicker the further we descend. Two to 3 km beyond the pass the path descends to a broad valley depression and we

arrive at the hamlet Kelateh-Allah-yar. A qanat covered with a platform irrigates figs, pomegranates, and a few fields. There are dark green eruptives here with veins of lime (Rock Sample CXIX); the jointing strikes east-west. The stream now grows 15 to 20 m broad. We encounter a gneissic rock with malachite and siderite, discolored by iron, intensively weathered, and crumbling (Rock Sample LXXV). Soon we again come upon the flat-pressed fault breccias; to the left of the valley they strike 60^{o}, to the right, 140^{o}. Later we come upon a vein of malachite striking 20^{o}, evidence that the rumors we had heard of copper in the Bakaran Mountains were certainly not without basis. Our path, which has been running for 3 km on a 140^{o} course diagonal to the line of strike, now swings around to 215^{o}. We soon reach the margin of the mountains, which is set off in piedmont steps, as it were, from a hilly area. The latter is transected by numerous gullies and dotted with a few inselbergs; it merges to the plain of Majan, which is bounded by the all-dominating Shah-Kuh.

We repeatedly encounter nonirrigated cultivated land. An attempt is made here to raise wheat with dry farming. The ground is now (15 March) being broken for seeding in the broad river bed (which we are about to cross). The peasant makes use of the moist ground to gain a little extra grain, taking his chances on the possibility that the bed will be flooded. Frequently <u>bands</u> are set up, i.e., small dikes on gentle slopes which catch the sheet flood, moistening the ground with the dammed up water.

The river now narrows. We break a sample from a dike rock (Rock Sample LXXVI) with 160^{o} strike and vertical dip. We move along sharply dipping yellow conglomerates on the right to

Chashmeh-i-Sard (Cold Well), a place consisting of 7 farms and 7 ruins. The cotton from the abundant crops here is spun locally and woven to beautiful Chadurs (woman's cloak) with yellow borders. The poverty-stricken people, who for example had in February only one cow, one rooster, and 7 hens, gain some extra income from the sale of their fruits (mulberries and pomegranates) and from transporting second rate firewood to Birdjand.

There are 2 routes from Chashmeh-i-Sard to Majan. We shall discuss first the direct one, which we took on 20 January and 11 February.

(1) To Majan via Kelateh Mollah-Khodadad (Mullah God Gave It). We move along an incised stream bed about 20 m deep, past cotton fields, sheep pens, and a small dike. Six km beyond the pass the rock begins to change constantly. There are steeply dipping, heavy iron-bearing conglomerates with 10° strike; later they dip only 30°. Still later phyllites, gabbro, eruptives rich in hornblende, and tuffs appear in the river bed. Soon the path leads downstream between 2 streams over a gently rolling semidesert with scrub vegetation. The clastics, which at first were about the size of a child's head, become even smaller the further we go from the foot of the mountains. After 9 km the 2 farms and the gardens of Kelateh Mollah-Khodadad come into sight 200 m to the right. Looking back to the mountains, we see that the confused green and red folds tower to pointed cones further to the east. In January they lay under snow.

Our path now leads to the right, cutting diagonally across numerous erosion channels which grow deeper and deeper the further downhill we go; eventually they are incised 5 to 10 m, forming a

rolling terrain. To the left is the unusual crater of the Aghal-Kuh-Givshad which we shall visit on the parallel route to Majan. To the right is the Siah-Kuh; the path soon turns and heads toward the latter. At the end of 15 km we pass 2 ruins one km to the right, remains of a past civilization. Moving downstream along a stream bed we find outcrops of tuffs and eruptives rich in hornblende. The path now leads along 2 dry beds between the Siah-Kuh and a few hills which rise from 20 to 60 m above the plain. At the foot of the Kuh-Siah we break a sample of melaphyre, the same which we later find with steeply dipping tuffs (in Rock Sample LXVII). An abandoned hauz stands in the foothills. This together with a number of dams up to one m high, indicate that the land here was formerly more intensively cultivated.

We now cross a number of shallow, sandy gullies with frequent piles of gravel on their slopes. At the nineteenth kilometer we break samples of melaphyre and tuff from a small subdued ridge trending east-west. Here again we find abandoned retaining dikes. There is a small spring which dispenses a little water.

The vegetation on this steppe consists chiefly of saltwort. Two and one half kilometers before Majan the ground is either very smooth and strewn with dark sand or irregular and strewn with clastics up to the size of a child's head. Later we cross the stream which has accompanied us to this point; it is 4 m deep here, but the banks are not steep. We are now moving across a smooth desert steppe; there are no salt efflorescences, however. There are artemisia, saltwort, and the spherical hedge hog plants until we come to a small chain of hills with melaphyres and small agates. Tuffs overlain by sandstone and conglomerates now appear; they drop

away in one stage to the fruited plain of Majan. The local inhabitants have dug caves as much as 20 m deep in these tuffs as places of refuge in time of danger.

(2) To Majan via the Kuh-Givshad. On 15 March we went from Chashmeh-i-Sard to Majan along the other path, the one via the Kuh-Givshad. It leads across numerous bands for almost a kilometer to the village of Khaliran with its many gardens. Another 800 m and we reach the hamlet Aliabad, which consists of only 2 farms; its rather extensive wheat fields have taken on the reddish brown color of the conglomerates. With the Kuh-Givshad on our right this time we move downstream along a stream bed, on the banks of which salt efflorescences once again appear. Since such efflorescences appear only to the east of the Kuh-Givshad, one might assume that there is a rain shadow here; but it is difficult to see why the rain should come only from the west and why the mountain, which is barely 60 m high and 200 m long, should have such a strong influence. It is possible that the horizontally bedded, coarse sandstone rocks and conglomerates have a connection with the formation of these salt efflorescences. They are unconformably bedded over the tuffs and eruptives and are obviously a young formation.

The Kuh-Givshad has perhaps the most extraordinary appearance of all the mountains of eastern Iran. It is almost perfectly circular; from a distance, with its slightly closed, only somewhat jagged crater rim, it looks like the work of a great meteor; a closer look however reveals that this small "lunar crater" with its eruptives and tuffs is undoubtedly of volcanic origin. The crater with a radius of about 75 m, has a very beautiful, uniformly high somma which drops abruptly as far as the tuffs, where the slope

becomes gentler and then merges to the crater bottom. The crater was undoubtedly filled at one time with a small lake, but the water created an escape to the south in the form of a meandering ravine which on occasion serves to carry away the heavier precipitation. In general the tuffs are overlain by hornblendic effusive rocks (Rock Sample CXXVII). (Dyer (43), Skrine (129), and Gabriel (62), mention a crater in Serhad west of the Kuh-i-Taftan which is regarded as a meteorite crater. On the basis of its form it would appear to be similar to the Kuh-Givshad.)

A second noteworthy phenomenon is a waterfall in the peculiar conglomerates near the Kuh-Givshad -- a rare sight in this area where the streams have leveled everything. The sandstones, broken into great blocks, are bedded up to the edge of the stream.

Leaving a village 500 m to the left, the cattle of which find a little pasturage near the Kuh-Givshad, we move through low hills constituted of red eruptives and once again come to the stream with its conglomerates. After wandering for a long time over a desert-like steppe and rolling hills with numerous bands on the gentle slopes, we come to an escarpment made up of the familiar horizontal conglomerates and sandstones superimposed on tuffs. A 2-km long qanat comes to the surface here; its water was 20° C on 30 January. Not far from the source it powers the mills of Majan.

One and one half kilometers before Majan we come to the village of Gulund, which lies halfway up a hill crowned by a ruined refuge fort. We move across numerous fields and djubs and arrive at the main center, Majan.

Except for Sykes (151), only Gabriel (135) has made a report on the Bakaran Mountains; he crossed them further to the east. He found a brecciated limestone, flattened clay slates, and porphyrite in which, near Chinist, an extensive cave with "Munien" has been formed. In the south he found gabbro, andesite, and dacite; further on, amphibolites and serpentine. In these mountains, which have a surprisingly dense population, beets are cultivated in nonirrigated fields; they frequently take the place of bread. The mountain settlements, which are situated at elevations of over 2,000 m, have poplars and nut trees -- which are characteristic of the area -- but otherwise suffer from a shortage of wood.

A particularly noteworthy feature of the Bakaran Mountains is the fact that they trend along the edge of the Lut, first east-west, then ESE, later southeast, and, finally, SSE. The northern and southern mountains stand in similar relationship to the Shah-Kuh; but except for those of Hedin, I have received no reports on the alignment in the mountains west of Neh. Clapp (30) determined that in the eastern part of the East Iranian Mountains, from Gunabad south, a meridional trend is predominant; but he did not report on alignment in the western part.

The extremely complicated structure of the Bakaran Mountains can be explained only after thorough special studies have been made. On our one trip we were able to establish several different foldings. After the folding of the widespread chloride slates a transgression took place, the basal conglomerates of which can still be recognized. The unconformably bedded calcareous sandstones were recently subjected to orogenic movements. This was undoubtedly followed by a period of faulting during which the

Birdjand valley depression with the Shur-Rud or Rud-i-Birdjand was formed in clearly recognizable en echelon faults.

Thus the northern front of the Bakaran Mountains was certainly formed diastrophically and the same is probably true of the westernmost part as well. We frequently found these directions to be the main tectonic lines.

To the north of the Kuh-Rich are twice-folded mountains relative to which the graben of the Birdjand valley depression is sunk.

South of there we encounter another type of mountain. With their gneisses, mica schists, and phyllites, all sharply folded in a unit, with their fault breccia and overfaults, and with the alternating directions of strike, they are recognizable as mountains under great tectonic strain very similar to the residual fold mountains in and around the Lut. At the present time we cannot say how much of a connection there is here, if indeed there is any. The Bakaran Mountains, with their gabbro, serpentine, and chlorite slates, have no counterpart in the eastern Lut.

The Kuh-i-Rich and its neighbors to the west probably represent a fissure eruption. These eruptives formed the crest, but were later isolated by the retreat of the watershed. This interpretation is strengthened by the noteworthy fact that the Kuh-i-Rich towers high above the surrounding area, despite the fact that it lies 5 km to the north of the present-day watershed.

Of the phenomena along this part of the route, the Kuh-Givshad and the nearly conglomerates deserve very special attention.

Unfortunately our photographs were destroyed so that it is impossible to present a picture of this amazingly symmetrical truncated cone. It has the embryonal form of a volcano in a mid-stage of development leading over to the explosion pits [maaren]; it must have been formed by a single explosion. Judging by the young forms, this eruption must have taken place in very recent geological time. It is doubtful that the present-day amount of precipitation could have caused the crater lake to overflow; for undrained basins are no rarity at this elevation (1,580 m) on the edge of the Lut. It is therefore likely that the crater was drained during a period of precipitation. It must have lasted a long time, since the long profile of the escape channel is already in equilibrium. The peculiar conglomerates and sandstones are younger than this small volcano; they can be traced as far as the erosion margin of the narrow Majan valley depression. They are evidence of a great gravel deposition which we shall encounter again just this side of Khusp, near the end of the route. We shall deal with this later.

B. Majan to Karimabad

(a) Majan

Between the Bakaran Chains in the north and the Shah-Kuh Mountains in the south lies a moderately furrowed plain broken by isolated hills and small mountains. In its center, along the westward flowing Karedjan River (called Rud-i-Gaz, i.e., Tamarisk River on the English map) is a fertile alluvial plain, the Djulgeh of Majan. Rimmed by high mountains but open to the west winds, it receives a great deal of precipitation; the snow in the mountains maintains the moisture into the spring of the year. Because of the good soil and the ample water supply there is a greater density of

villages and settlements here than anywhere else in Qainat. They lie in a circle extending from 10 to 15 km around Majan: to the northeast are the villages Karizak, Gulund, Kuzab, Homsab, Kelateh-Sarkar, Afridabad, Karimabad, Aliabad, and Kadj; to the southeast are Kushe, Hesarat, Naktabad, Sardabad, Fesiabad, Akbarabad, Huseinabad, Kushe-Shah, and Mahmud; to the southwest are Gurian, Talkhabad, Peirut, and Mahmedabad; and to the northwest Alabad, Kararik, Sharafin, Deh-Mir, and Gangou. It is noteworthy that the population thins out to the west and finally ceases, for here there is no mountain wall, and the water becomes salty and the ground turns to desert with kavir formations.

A surprisingly large part of the land is cultivated without artificial irrigation. The broad funnel of the plain, open to the depressions of the Lut, the relatively high elevation of the area (1,400-1,600 m), and the amphitheater form, all work to insure abundant precipitation during the rainy season and prevent the falling snow from melting immediately. Therefore it is possible to practice various types of nonirrigated farming without involving too great a risk. Of the nonirrigated fields, some are left fallow and without manure for one or 2 years, while others -- usually in the immediate vicinity of a village -- are fertilized and planted regularly. Manure, to be sure, is scarce for it is also used for heating. Land that has lain fallow is preferred for cultivation without irrigation.

The fields are cultivated primarily with wheat, barley, millet, fodder beets, and all sorts of vegetables. Fruit, of which there is but little in the salty depressions, is cultivated extensively in the wind-protected valleys and is bartered for the

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grain grown in the plain. Cattle are bred extensively. In addition to the usual sheep and goats there is a surprisingly large number of cows, additional evidence of the relatively great precipitation in the area. It is not unusual for a single household to have 3 or 4 cows; unlike the sheep and goats they give milk in the winter as well as the summer.

Majan proper, the largest center in the area, has about 100 houses of the usual domed structure with small badgirs open to the NNW. The grain is threshed on numerous floors rimmed by low walls of loam. It can be taken immediately to the nearby watermill, an extraordinary gift of nature here on the edge of the desert. Nevertheless the numerous ruins are witness to the fact that Majan -- like all peasant settlements in eastern Iran far from the mainstreams of traffic -- must have declined in population. Here too opium smoking is widespread. In addition to a mosque and a school, Majan has a refuge fort; but, like the town wall, it is fallen to ruin, a sign of general peace. On a small isolated hill to the west is the residence and garden of the local potentate.

Because of the greater abundance of water, the plain of Majan is far more densely populated than that of Birdjand. It is broader and open to the west winds, while the Birdjand valley depression is narrow, especially at the head. On the edge of the valley depression the rain winds are confronted by mountains 2,000 to 3,000 m high, with the visible result of a genuine river which, swelled here and there by the abundant snow of the Bakaran Mountains, contains water throughout the year, an extraordinary rarity in eastern Iran. We shall encounter this river again in the last part of our route.

Despite the fact that its location in the area is more nearly peripheral than central, Majan is a market place; this can be attributed to the spring near Gulund which powers the only water mill in the area.

Two kilometers south of here, on the other side of the river, is the ruin of a solidly built castle with tower, walls, and a moat. It is situated on the highest peak of a small chain of hills about 60 m above the valley floor. According to the tales of the local populace this is the remains of a castle of Rustam's daughter, Majan, whence, they say, the name of their place. It probably belonged to the Assassins. The answer could probably be easily ascertained on the basis of the clay and glass shards, of which there are many. The hills themselves are constituted of hornblende andesites and tuffs with numerous quartz crystals. To the southwest of the Kuh-i-Rich, which is clearly visible from here, I was shown a mountain said to contain the Qal'eh-Rustam. In any case this area might be an excellent site for archaeological work.

(b) Across the Kuh-Shah to Karimabad

On 16 March we left Majan and proceeded southward across the chain of the Kuh-Shad to Karimabad. Since this mountain, which towers over everything, is the last great elevation before the Lut Desert, it seemed to us important to determine what sort of material it is made up of. Through wind (from the southwest) and rain we proceed between cultivated, later fallow, fields with the mountains Karedjan and Malgulan on the right; these flank the cultivated plain in the west. After 1.7 km we cross the Karedjan River and pass between the hill with the castle and an elevation of andesite hills into an extensively cultivated plain hitherto

hidden from our sight by these hills. After 4 km we reach the village Wakhtabad, which consists of about 20 houses and numerous ruins; there is a little salty water here. Numerous villages are visible to the east. A few hundred meters more and we arrive at the village Akbarabad with large orchards, chiefly of pomegranate and almond trees. Beyond this village the cultivated land gives way to a slightly furrowed steppe. Another kilometer and the ground is covered with the familiar rock debris and pavement, probably indicating that the cultivated area included the steppe at one time. There are various dikes in the river on the right. We had already determined that the cultivated area formerly extended further than today on the north side of Majan.

Soon the terrain becomes more diversified. To the east is a small sharp-peaked mountain, probably of eruptive rocks. The river we follow now has terraces. After 14 km we reach Shaikhabad, a village consisting of about 50 domed houses, the walls of which are constructed of a melaphyre which we encountered just before reaching the place (Rock Sample CXVIII). We now have a clear view of the mountains, and as we move along we note 3 clear-cut terraces, 10, 50, and 150 m above the valley floor, embedded in a level about 400 m high. At the end of 18 km we reach the village Mazar-Shah in the midst of a hail and thunder storm; the aneroid is falling. At this time of year 16 persons including children live in the 10 dome-roofed houses of Mazar-Shah; in the summer the population is much greater because of the influx of families from Majan. In the many orchards grow mulberries, apricots, pistachios, almonds, walnuts, and apples, the latter of the renowned Meshed quality. This fleck on the map also attempts to compete with the Khurasan metropolis with a holy grave; it is idyllically located under poplars

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3 km to the south and is supposed to contain the body of an imam. To the north of the village a ruined fort stands on the second terrace of a branch of the river.

Wheat and cotton are grown on the terraces, sometimes with djubs, sometimes without. The town's one and only cow is used in the planting. Sheep and goats are numerous. If there is a heavy snowfall during the winter, the river contains water for a long time and a good harvest can be counted on. Various similar locations in the south and east keep houses ready for summer evacuees. The entire area is called locally "Kuhistan," a name frequently applied to mountainous areas in Iran. Almond and pistachio trees are common here as well as zygophyllum and tamarisk.

The way leads to the tiny nearby village of Shanedu, located on the 10-m high gravel terrace, and from there to the second terrace, which here extends over eruptives with kaolinized feldspars. It merges with a broad plain, which we follow; the latter is overgrown with tamarisk and thistles. The river bed narrows to a gorge beyond Madnuk, a village 1,775 m high with 5 houses and gardens; at this elevation there are no pistachios. In order to reach the neighboring valley we climb across an interstream plateau with tamarisk up to 2 1/2 m high and sparse artemisia. With the increasing elevation the tamarisk dies out, the saltwort becomes less common, and the thistles give way to Tedaeh kuhi (mountain plant). The distinct terrace configurations also appear in the new V-valley at distinct levels. The valley, in which large stone blocks lie, soon becomes steeper. The path zigzags toward the pass. We reach it on 17 March at 1100 hours; the temperature is 0° C, there is snow and fog, and the north wind is blowing sharply.

The elevation here is 2,290 m, 860 m above the Majan plain; but of course there is no view. We take specimens of an eruptive rock (Rock Sample CXIX) and of a lime and iron-bearing dike rock (Rock Sample CXX).

The path leads steeply downhill along rock walls; the deeply incised river is in the process of forming a terrace. There grows here, in addition to tamarisk, artemisia, and the mountain plant mentioned above, a type of rhubarb called rivas which is collected for use as a vegetable and as a hair dye. When the valley narrows to a gorge we leave it and climb uphill across a stony pasture land, then downhill again to the small village Mazar-i-Surban, situated in olive orchards on a 15-m high gravel terrace. As we move along the left terrace of the valley, which is broader now but without water, we observe gardens in the river bed. Apparently the people here have no reason to fear great floods. We leave the valley and climb to a small height which affords a view of a broad river bed and a peneplaned hilly area with numerous peaks; it slopes off toward the north, rather than the reverse, which we had expected.

The hills are made up of conglomerates and sandstones with veins of lime which strike 120° and in the beginning are vertical; they apparently lie over the eruptives we have passed. As we proceed downhill we observe east-west strike with dip to the north; the uniform height of the peaks is amazing.

Twenty kilometers beyond Mazar-Shah, just before we reach a new narrows, we come to the village Kalai; its 20 dome-roofed houses of stone are situated in a broad eversion with abundant room for fields. To the right lie the villages Bid and Chadur. The

narrowing of the river results from its entering eruptives (Rock Sample CXI and CXXXI). We move across these eruptives and step out onto the great pediment of the Shah-Kuh, then travel downhill almost 20 km across the latter to Karimabad. To the left at the margin of the mountains we see another village, the last sign of civilization we encounter till we reach Karimabad. Tamarisk one-m high still grows in the bed of the river. It is interesting to note how the material on the surface grows constantly finer. Thirteen kilometers beyond the margin of the mountains the streams and smaller rills are completely subdivided. The surface is covered with sand and gruss with only occasional appearance of coarser detritus. Then begin the deflation hills overgrown with tamarisk. Another 1 1/2 km and the coarser debris disappears completely; after 15 km sand and loam and kavir formations begin to appear. Salt efflorescences cover the slopes; only where small bands have been set up is the soil desalinified. After 19 km we arrive across sand and dunes at our goal for the day, Karimabad.

According to our observations the crest of the Shah-Kuh, unlike the parallel chain to the north, is constituted of eruptives; they could not be definitely classified macroscopically, but in other routes west of here we encountered hornblende andesite in the Shah-Kuh. The characteristic features of the northern slope are the 3 terraces of the river course; they are embedded in a higher level which could also be described as a trough, and significantly -- are parallel to those of the Shuragan Valley. Their sharp divergence from each other is indicative of intensive deformation.

A second outstanding feature is the level which unites the sedimentary hills. It lies before the eruptive mountains as an

inclined step. Since, contrary to the rule, it slopes to the north, one must assume that it was not only formed after formation of the summit area but in relatively recent times, and that this formation was accomplished over a great crustal block. Otherwise the slope would be reversed. These sedimentary accumulations must be older than the eruptives which lie over them and -- at least in part -- the same age as another eruptive series which is interbedded in them. One is tempted to equate these conglomerates and sandstone rocks to the fold mountains observed to the north of the Kuh-i-Rich; these are also overlain by eruptives. But this could be confirmed only by special investigations.

C. From Majan to Hamund

We traveled the stretch between Majan and Hamund on 19 January, 1 February, and 10 February. On the last trip I was sick and therefore not able to make any observations. The results of the other 2 trips are summarized here.

From Majan to the Karedjan River the way leads between cotton, wheat, and barley fields which are often separated by low walls. After turning to the southwest it leads across pasture land and a dry farming area, the latter evidenced by the numerous bands. The salt efflorescence, the first we noted in loamy soil, had been washed away by the rain on the second trip. We cross a djub and a qanat and after 3 km come to hills of eruptive with large hornblende crystals (Rock Sample CXV). After 4 km we descend to a deep stream bed coming from a garden village on the left, then move up a gentle incline along a smooth path with gray hills to the right made up of the same eruptive or of olivine basalts. We cross 2 stream beds about 10 m deep and in the fifth kilometer note a

hauz on the right and on the left low hills mantled with talus. The terrain then becomes flat; a sparse vegetation of saltwort and spherical spiny plants grows in the stony soil. The few stream beds are shallow but have banks on the right as much as 50 cm high. Their pebbles are frequently of an aplitic rock (Rock Sample CXIV). The hills are built up of hornblende andesite, later of dark olivine basalts; after 7 km these give way to a chain of hills of light gray andesites. Before us to the right the hills rise to a peak of yellowish rock; it is called Kuh-Garshun. Beyond the eighth kilometer the terrain is dissected by numerous broad stream beds. To the left is a fairly high peaked hill situated before the mighty Shah-Kuh; the latter remains on our left throughout. The first stream bed is 12 m broad with steep, uneven slopes and with clay kavir formations or salt efflorescences in the tributary channels; the second has 10 and 15-m slopes left and right respectively; the third is 8 m broad and incised 6 m deep; the fourth is similar to the third. Since the terrain slopes off to the right, the streams, which contain isolated growths of tamarisk, are cutting down. Here and there we encounter grazing camels.

In the ninth kilometer, where our path, which is strewn with sun-cracked rocks similar to basalt (Rock Sample CXVI), holds along small hills to the left, a path branches off to the Shah-Kuh. This first and last branch to the left confirms our assumption that there are but few settlements west of the area described in the previous section. In the tenth kilometer we cross a broad stream bed incised into the basaltic rock which outcrops here. Its tributary channels bear salt efflorescences throughout; we frequently cross small stretches of kavir. In the eleventh kilometer there is another broad, sandy stream bed with andesites in the gravels.

The path which now leads through a slightly dissected hilly area, is covered with fragments of olivine basalt and green eruptives with hornblende dissemination lines. Later loam is predominant and only the small heights bear angular fragments of dark green eruptive up to the size of an egg; the water courses contain pebbles up to the size of a child's head. From here we can see the Kuh-Madenug to the north of the Shah-Kuh. Its crater is drained to the northwest into the broad Qal'eh-Lak-Tshapan River. The latter, flanked by the foothills of the mountains, has andesite or dark green eruptives in its gravel. The path crosses this river in the fifteenth kilometer; further upstream by the dry bed there is said to be the ruin of a castle -- as indicated in the name Qal'eh.

We have now entered into the spurs of the Shah-Kuh. A path branches off to the right to the village Peirut, the westernmost settlement on the plain of Majan. After crossing a river bed 80 m broad we come upon the road to Khusp. It joins with our path which now leads up a broad valley with massive, horizontal conglomerates 10 m thick on the right slope. After 19 km we arrive at Hamund. (The stretch between Hamund and Karimabad will be described in Section E.)

The route from Majan to Hamund did not disclose anything sensational, but we observed that the ground north of the Shah-Kuh is constituted of eruptives and that the streams flowing down from the mountains bear pebbles of this rock only. The clearly visible somma also bespeaks the volcanic nature of the Shah-Kuh. The stretch is divided into distinctive sectors. From Majan onward lies about 200 m above the present-day surface a level of peneplanation which surrounds the various hills and inselbergs.

It merges to this top surface, which is only slightly dissected. At the point where the present-day surface begins to slope more steeply the terrain is transected by numerous stream beds and there are isolated inselbergs not connected by any apparent uniform surface. A third type is an area dissected by small trenches; further down where the wadis are more deeply incised, there are inselbergs. The fourth type is the mountainous area of Hamund.

If we attempt to reduce this stretch to a common denominator we see that there was once a level over which towered isolated residual knobs. This level was broken up by erosional processes of varying intensities; wherever the present-day surface is but little dissected it can be equated with the old surface. Once again it is apparent that chemical weathering, salt efflorescence, and kavir formations occur only where there is water under genuine capillary attraction. Even in the dry river beds of the Shah-Kuh area where the water -- which is available only in the winter -- runs in, such formations are not possible. We shall deal later with the horizontal beds of conglomerates of Hamund.

Locally Hamund is also called Hammond; the correct name is probably Haman (spa). Of its 30 houses, half are empty. In its extreme poverty it is another example of the fate we described in connection with Deh-Salm (Route I). It had many camels once, in the days when camel breeding was profitable, but today it has none. Once it was populated entirely by free peasants, but today many have sold their water rights to the lords of Khusp or Karimabad; they sold their "Shaban-u-Rus" for 2,000-2,500 rials (400-500 marks) and moved away -- those who did not succumb to the opium habit. (A Shaban-u-Ruz (Day and Night) is the right to inundate a field

with djub water for 24 hours according to a locally established rotation plan -- every 13 days here.) The manor lords hire peasants only as field workers and pay them 1/4 of the crop for their work. Hamund, which has very rich soil, grows chiefly millet, beets, and wheat; the yield is sometimes 50 times as much as the original seed. There are a few pomegranate and mulberry trees. The home industry is restricted to the making of mats from the wool of the area's few sheep. Of course the area has suffered greatly from plundering. The Baluchi dared to make one last attack as late as 1920; the people fled to the Shah-Kuh Mountains as the robbers approached.

Hamund has no qanat. The fields are inundated in part with surface water. Once again we note how characteristically free peasants and surface water go together (although this village subsequently fell into bondage because of exceptional bad fortune). The most characteristic climatic phenomenon at this elevation (1,500 m) is the wind, which is deflected to the west by the Shah-Kuh and gives the area its characteristic rawness, for the pass is a bad vent hole. To be sure, this works out very well in the summer. The north wind, which we encountered constantly here in January, held the diurnal temperature between 5 and 10° C, but did not bring frost; the latter is not unknown here however. Cumulus clouds at a height of about 800 m around the Shah-Kuh covered the north slope with snow, but on the south slope there were only a few patches. We were told that in Hamund itself snow falls very rarely and never lies more than 2 days. According to the inhabitants, the north wind, which blows strongly throughout June and July, makes the summer heat bearable. Therefore there is a summer influx into the area of nomads from the vicinity of Birdjand; their herds find pasturage around the Shah-Kuh.

The 2 loess terraces east of Hamund have apparently been artificially leveled. The upper one, paved with clay concretions (Rock Sample CXIX), is covered with so many relics of clay vessels that archaeological excavations here would almost certainly lead to success. The streams between these terraces have cut down through the loess and are cutting into the bedrock. The attitude of the bedding indicates that the loess was deposited in a period after the gravel deposition but before the downcutting. The lower terrace is under cultivation today. Just how the loess could have been deposited here in windy Hamund is not entirely clear, but it is possible that the pass to the south of here on the road to Sar-i-Chah creates an air swirl when the south wind blows, thereby necessitating deposition.

(It was recently asserted (14, page 17) that genuine primary loess had not been found anywhere in this entire arid upland. The question of loess in inner Iran is not a new one; von Niedermayer stated, "in general its distribution is amazingly limited." But he states in conclusion that "earlier it must have been deposited in greater thicknesses and over much greater areas" (106, page 46). He believes that the Iranian depressions were undoubtedly once filled with loess. Other authors have also mentioned loess, though only in isolated occurrences. Hedin discovered the important terraces of Turut and also discovered loess alternately bedded with sand south of the Great Kavir. Gabriel (58) discovered 20-m high loess walls south of Bam on the north slope of the Djebel-Bariz in the valley of Rudkhane Segeidin which could not possibly be considered aqueous loess. Gabriel also established its presence in the south of the basin of Shah-Dat where the grandiose 70-m high "boulevards" are built up of this material. On his first expedition

Gabriel (58) found loess west of the Lut, 20 km southeast of Bahabad, in which the local people used to dig stalls with air holes for their sheep and goats. Sykes (152) reported loess between Tshehil-Payeh and Darband which was disintegrated into bizarre forms. To be sure, according to Clapp (30), the great loess accumulations are to be found in northern Afghanistan, in Gurgan, and northwest Khurasan, but it cannot be said that loess does not occur in the arid upland. I personally also found it south of Basiran, as will be noted later. Of course it is blown out of the central deserts and is therefore usually found in their surrounding areas.)

D. The Basin of Sar-i-Chah

We crossed the Sar-i-Chah Basin several times, stopping over in its main center, Karimabad; the latter is usually referred to by the name of the general area.

To the north the basin is completely closed off by the dominating heights of the Shah-Kuh. In the west, separated from the Shah-Kuh by the pass at Hamund, are the Hassardar Mountains, followed by lower chains called Kuh-Honuk and Kuh-Gamberu. In the southwest is the subdued ridge of the Siah-Kemer, situated in front of the Chah-Doshi and the Peterki, the heights which close off the basin in that direction. In the south are a few isolated hills which do not close the basin off completely from the catchment area of Basiran.

The basin is drained to the west by the Shur-Rud and its tributaries which stream down from the above-named mountains, but it is filled with the most diverse sorts of kavir formations. The bedrock probably consists for the most part of eruptives, but in

the southwest we came upon peneplaned fold mountains by phyllites, mica schists, and serpentines. The malachite veins there once led to an attempt at copper mining, traces of which are still visible.

Evidence of this mining is provided by a special path from the village Basgeru (4 km west of Karimabad); we traveled this path on 15 January. Basgeru, a village with about 30 domed houses, has a few wheat, beet, cotton, and millet fields, irrigated with salty qanat water. But only one km south of the village, sand kavir begins. The water channels of the nearby small hills, which consist of eruptives, are filled with sand. We pass a small height made up of gypsum and after 9.5 km come upon phyllites dipping slightly to the south (Rock Sample LVIII); they are overlain by talcose serpentines with epidotic glide planes. Another kilometer and we find hard mica schists; still 1.5 km further are serpentines and then mica schists striking 160° and dipping 35° ESE. We cross a river with a little water, which has cut 10 m deep into its gravel; it has hard amphibolite "Kanzeln" in its bed. We come upon mica schists striking 150° and then reach a chain of hills disassociated from the Tshardasi; in these hills we open a reddish vein with traces of metal (Rock Sample LX). The streams running down from this rather high mountain also have sharply folded mica schists striking 150° in their beds. We can observe these (as in Route I on the way back) sharply folded, carved out of the degradation plain. The larger drainage channels always exhibit 3 terraces, the upper 2 rock-cut terraces, the lowest one a gravel terrace.

Thus proceeding from east to west, we encounter first the eruptives of the Shah-Kuh, then the hills of sandstones and conglomerates (see above), then eruptives again, and finally the old

peneplaned fold mountains in the southwest. As we have already noted, the Shah-Kuh slopes down along a long alluvial cone which becomes somewhat steeper where it merges to the Sar-i-Chah Basin. Hedin who was in the basin from 24 to 26 March and crossed it in a southeasterly direction, brought back rock specimens from Tshemeshme-i-Sehesid on the northwest edge; they were described by Asklund as reddish gray andesite tuffs, yellowish brown dacite tuffs, a reddish brown rock probably of volcanic origin, bright red vitric tuff with andesite fragments, andesites, and greenish limestone with tufaceous materials.

Little is known about the climate of this area. Our notes are based on our own observations and on the statements of the local inhabitants; the latter, of course, are not always accurate, but have a certain value when compared with the climatic trends of the neighboring areas. The all-important rainy season usually begins here in January. In 1932 the first rain, mixed with hail, fell on 17 January. On our second visit to Karimabad on 4 February the sky was covered with stratus and stratocumulus clouds; a few raindrops fell, accompanied by strong gusts of wind from the south. On 7 February there was a thunderstorm and in the shortest possible time the atmospheric pressure fell notably. At 1015 hours when the temperature was 11° C and the wind from the south, the aneroid read 662.5 mm; at 1230 hours with the temperature at 13° C, there was a violent sandstorm from the south and the reading was 657 mm. Then came a short, loud outburst of thunder. At 1400 hours the wind, which had been blowing for 4 hours, shifted, began to blow directly west, and swept the sky clear. At 1430 hours the aneroid fell to a low of 656.5 but almost immediately began to climb rapidly. For days thereafter it remained at 663.5 (reading at 0830 hours);

the temperature remained at 15°, the skies were clear, and there was no wind. (For greater detail see 146). On 9 April there was a thunderstorm a little to the south of here with a little precipitation; otherwise we observed no rain. A few interesting indications are to be gleaned from the statements of the inhabitants. At the beginning of January and at the end of February Birdjand had extraordinarily heavy snowfalls, whereas in Sar-i-Chah there was no precipitation in January and very little in February. On the other hand, it rained heavily in Sar-i-Chah on 26 March while we were in the midst of a sandstorm in the Lut. The slight rains we noted in Qal'eh-Seri (about 100 km SSW) also fell on Sar-i-Chah at the same time according to the inhabitants. They say that by May the basin has no more rain, but that in the Shah-Kuh thunderstorms often continue into the summer. According to Khanikoff there was no rain during the last 3 weeks of March (1858).

Sar-i-Chah lies 200 m lower than Majan but precipitation in the 2 areas varies so greatly that the difference can hardly be explained solely in terms of elevation. Moreover the fact that the considerable precipitation in Birdjand has little or no effect here indicates that the basin has a peculiar climatic position which is probably determined primarily by the surrounding mountains.

We were able to learn only a little about temperatures. During the time we were there they varied between 2 and 25°. There was no frost during the nights, but the local people informed us that frost is a common occurrence. Ice formation is rare and it is said to melt during the day. Snow is almost unknown here in

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the plain and never lies more than a few hours. Because of the rarity, a few days of extreme cold accompanied by north wind (i.e., undoubtedly a cold air front penetration) are well remembered; we noted such evidence of cold air penetrations as far as Deh-Salm. But the lack of date cultivation cannot be explained solely on this basis, for dates are grown in Naiband, which, to be sure, is almost 200 m lower, but also somewhat further north and certainly no better protected. Date trees also grow in Zanagun, which is even farther north (see page 150), and even in the northernmost areas of Gulshan, where, to be sure, they often suffer heavy set-backs from cold air. Khanikoff reported palms in those areas around Sar-i-Chah sheltered from the north wind, but I was not able to learn anything of them; nor did Hedin report them.

In the spring the temperature rises so rapidly that on the first day of spring most of the inhabitants desert the villages and move into tent camps or seek out cooler villages at higher elevations. The reason for this is not wholly climatic however. Whereas most of the inhabitants of Karimabad go 15 km south into the mountains to Radgaz, almost the entire population of Faizabad stays at home, despite the fact that the latter is 3 km south of Karimabad and at the same elevation. Unlike those of Deh-Salm or Shah-Dat, the summers in the Sar-i-Chah Basin are bearable, if not healthy. The spring migrations here are based not so much on climate as on the ancient law of nomadism, according to which the people seek out the spring pastures in order to spend the most beautiful time of the year there and to enjoy the fullness of milk which their animals provide them. This mode of living indicates that the inhabitants of Sar-i-Chah are basically half farmer, half nomad.

Undoubtedly the north wind is predominant in the summer, but the populace reports that on occasion the south wind blows, bringing dust and making the heat almost unbearable. The sand dunes travel south for the most part. However since typical dunes structures are very rare here, the reports of winds from the south are altogether believable, especially since Sar-i-Chah is almost completely open to the south. The extent to which the nearby Shah-Kuh mitigates the extremes of temperature is obvious from the fact that in the south and southwest, nearer the Lut, the daily maximum was always a few degrees higher than elsewhere.

The connection between mountains and civilization, which is characteristic of the arid regions, is especially notable in the villages of Sar-i-Chah. It is only thanks to the Kuh-i-Shah that a civilization could develop here on the edge of human habitation. Without the mountain, which dispenses water and life itself, this area would be desert of the purest sort. Fluctuations in precipitation, especially winters with little snow, are often catastrophic.

Majan, on the other hand, exists precisely because of the natural environment! Situated 300 m higher than Sar-i-Chah, walled in funnel-like by 2 mountain ranges, it has as water sources the north wall of the Shah-Kuh and the snow fields of the Kuh-i-Bakaran. Sar-i-Chah has only the southwest side of the Shah-Kuh and this side has but little snow and loses it much earlier in the year. To be sure, a little dry farming is attempted here and there with the aid of bands, but only when there has been a particularly heavy precipitation early in the year, and even then only at great risk. The barley yield from this nonirrigated farming serves as additional food or fodder, but the daily bread can be assured only through qanat irrigation.

In order to obtain fresh irrigation water the qanats must be extended through the gravel and fanglomerates of the alluvial cone into the vicinity of the mountains edge (see Route V for information on qanats). For this reason the villages far-removed from the mountains are very much at a disadvantage. Since the cost of building a qanat increases disproportionately with increase in the length and depth of the tunnel, the question of rentability -- entirely aside from all other factors -- limits the construction of qanats. On the other hand, it is also impossible to build villages on the pediment of the mountain; to be sure, the first settlements are right at the edge of the mountains or even in the mountain valleys, but these are followed by a stretch without villages, for the qanat tunnel must be led through the gravel and fanglomerate deposits and the location of the villages is determined by the location of the qanat outlet. Therefore the basin's eastern string of villages is located along a line beyond the alluvial cone where it is possible to have water outlets. We did find a few ruins east of here, but it was apparent that they had been abandoned because of the lack of water.

Water is also the chief weapon in the battle against salty soil. Salt, which occurs in traces even in Majan and which puts an end to cultivation there in the west, is a matter of life and death in Sar-i-Chah. One could say that the second great problem is irrigation, if the latter were not one with the problem of salt. The fact that fruit here grows poorly or not at all, does not result from a lack of water per se, but from the fact that there is not enough water to desalinify the soil to the depths to which the roots extend. The people must be content if they are able to desalinify a thin layer of top soil.

The second great enemy of agriculture is sand, for the wind can blow unhindered across the basin from almost all 4 directions. Only the winds from the east are slowed by the massif of the Shah-Kuh; they blow gently down its slope as foehns. The winds are laden with sand from the dunes which wander across the southern part of the basin. These are pushed toward the south by the predominant north winds, but then swirled up by the violent storms from the south, so that it is necessary to protect villages and fields with fences. The dust blown from the south is believed to enrich the soil in the fields. But sometimes an area is buried with sand in spite of the fences; the mosque on the northern edge of Karimabad is an example.

In spite of the hard struggle for water and against the murderous summer heat, the salt and the sand, there are numerous villages here, for the soil is rich and the plants grow rapidly. How many place names one can read of in Sven Hedin's works! But I must confess that I did not get to know all of them. The largest villages of the basin are Karimabad with 40 closely spaced houses (about 360 inhabitants) and Faizabad, with 60 houses chief among the southern group, which also includes Husainabad, Khairabad, and Kelateh. The seat of the government -- which holds sway over the area with a very patriarchal hand -- is Karimabad. Hamatsh, located at the edge of the mountains, is the easternmost of the numerous small hamlets and settlements. In addition to Karimabad, Aliabad and Sar-i-Chah are located at the edge of the alluvial cone. At the western extreme are Sardeh, Basgeru, and Sar-Chah-Shur. The last 2, both consisting of 25 to 30 houses, have only salty qanat water and must haul their drinking water from Karimabad. The 2 slowly dying fruit trees of Sar-Chah-Shur and the few carefully

fenced fields indicate clearly that in spite of all efforts it is hardly possible to improve one's lot under such circumstances. On the northern edge of the basin are the villages Hassardar, Sidu, Feisu, and Chashmeh-i-Sehisid, the latter the village where Sven Hedin pitched Camp No 54. The settlements may be classified according to their locations.

1. Those in the mountain valleys, e.g., Kalai.

2. Those at the edge of the mountains, e.g., Hamatsh.

3. Those at the foot of the uninhabitable alluvial cone, e.g., Karimabad.

4. Those in the basin proper, e.g., Faizabad.

5. Those on the western edge of the basin, e.g., Sar-Chah-Shur.

Every village needs its own qanat for irrigation. The rotation period here is divided into 13 shaban-u-rus. Thus whoever buys a shaban-u-rus (for the rather high price of 1,000 tomans) receives the right to flood his land on one of the 13 days. Usually however the poor people can afford to buy only a part of a shaban-u-rus from the qanat owner and are therefore able to irrigate for only a few hours at a time. As a result it is very easy for them to slip into dependency or even serfdom. This is sometimes carried to such an extreme that a whole family is obliged to hire itself out to the qanat owner as labor; as pay they receive only flat cakes, 3 for adults and 2 for children, plus a soup in the evening. In places the fields have been extended into the kavir soil, indicating how rich the soil is here when there

is sufficient water for desalinification and dams to hold the fresh water and keep out the salty water during the rainy season.

The crops grown here are the usual ones for this part of the world. Only the planting and harvesting sequence and the number of crops per year (2 to 4) are distinctive. Winter wheat, for example, can be harvested in April or at the latest in May. This is followed by plantings of millet or cotton, the former being harvested in the summer, the latter in the winter. With the aid of fertilizers, however, it is possible to have 3 crops, cotton, wheat, and millet in that order. If barley is sown instead of wheat, a fourth crop consisting of melons, gourds, or onions can be raised in a 40-day period between the beginning of spring and the end of May. In the latter case, of course, heavy use of fertilizer is necessary.

Melons grow especially well here and reach record weights. Wheat, which is sensitive to salt, is usually planted on the higher levels where irrigation is difficult; therefore the wheat grown locally is not sufficient for local needs. Moreover since there are no mills here, the grain must be taken to Majan for grinding or else ground with great effort with hand mills or even with simple stones. Therefore the summer villages plant barley in the bands to gain a little extra food. When the spring rains are heavy the people dare to plant barley in the basin proper, utilizing bands which are always kept in readiness; at the worst they gain a little extra fodder.

Where there is sufficient irrigation the area is amazingly fruitful. Even without fertilizer the wheat yield may be 30 times the seed, which is exceptionally good in eastern Iran. No doubt

the "dust fertilizing" helps. Manure is also available, for the people of Sar-i-Chah are experts in cattle breeding.

It is quite surprising to find fine looking cows here on the edge of the desert. These adaptable animals of the Zabolistan breed have learned to live here on desert plants, just as they have learned to live all year round on reeds in Zabolistan. Fodder plants are raised only rarely here, for the fields are too valuable. To be sure, the cows are fed the straw after the grain has been threshed, and in the spring they are driven to pasture in the mountains; but in spite of my inquiries I was not able to learn how they are kept in such good shape through the winter. In addition to cows and the usual sheep and goats the people here also raise good camels; but since the price decline they sell for only 50 tomans, whereas they formerly sold for 5 to 10 times that amount. The chickens are also of better quality than elsewhere, indicating, like all the animals here, that these people are not only farmers, but also nomads.

The stunted trees of the basin bear a few pistachios, almonds, and pomegranates; usually though, trees, and in particular almonds, are cultivated in the mountains or on the edge of the mountains. The grapes which were formerly grown in a few vineyards were destroyed, like those in Hoshare, in the locust plague of 1927.

Although the people of Sar-i-Chah can afford but few of the necessities of life, they nevertheless barter for such things as rice, tea, millet, sugar, tobacco, calico, sandals, petroleum, and last but not least, opium. In exchange they offer salt, gypsum, asafoetida Boiss and other medicinal plants such as tamarix manuifera

Ehrenb, and Astralagus florulentus Boiss. They also sell wood. They bring saxaul and tamarisk from great distances to sell it in Birdjand or Majan. Gummiresina Galbanum or Mutterharz Sarcocolla and mastix are also gathered. Now and then it is possible to sell a sheep or goat.

The local inhabitants also gain extra income from the caravans which pass through here on the route from Birdjand to Shah-Dat and Kerman. The stretch from Sar-i-Chah through the waterless Lut, the greater part of which we shall discuss later, is made in 5 manzels (stops made in the stretch covered in one day). But here, as at Deh-Salm, traffic ceases in the early spring and does not resume until fall. The caravans were formerly of great importance in communications between Meshed and Kerman; they still exist today, but carry only goods of low value. A part of the freight on the return trip always consists of dates and citrus fruits from Shah-Dat. Many of the inhabitants of Sar-i-Chah join the caravans as drivers, owners, or part-owners of camels, but they spend the hot summers with their families in a summer village.

The seasons are passed by the people as follows: In the difficult winter they have a little bread, millet gruel, and kashk (hard cheese made in the summer by cooking down the skim milk); boiled sheeps' feet, bought in the market, are a great delicacy. The spring is the best time of year because the animals give milk freely then, but of course a great deal of it must be cooked down and saved. The hot summer is spent caring for the cattle -- in the mountains insofar as possible. In the fall the fields are planted, the cotton picked, and the wood gathered; at this time they also seek work with the caravans. Still, the fresh nomad

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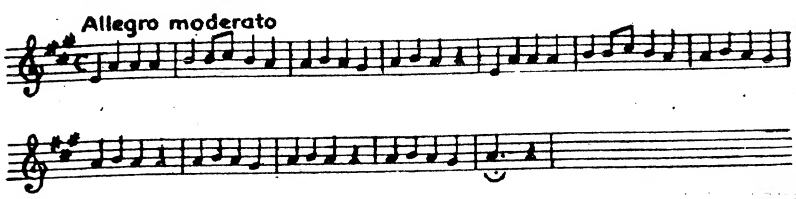
winds, which blow here at least part of the time, have produced a freer and happier race than in most villages of eastern Iran, where the harsh, always doubtful battle for existence is made even darker by the black shadow of Shiism. Religious songs are sung here, rather than verses as in most parts of the country. The following represents one such song insofar as it is possible to translate oriental music into our system:



The melody cannot be said to be very imaginative. The prayer callers, standing in the thickets of the summer camp, impressed us with their clear tenor more than their melodiousness. But here rhythm and mysticism are necessary, for fantasy requires damping rather than stimulation. The text is not very important.

Hedin, who pitched camp in Sar-i-Chah (76, page 139), did not speak well of the place ("One cannot imagine a more tiresome village."), although the settlement had 100 houses then, more than twice as many as at the time of our visit. The reasons for the decline have already been stated.

We cannot finish this section without a word about the inhabitants and their agreeable character. Hedin said of the women in the area: "many of them are quite good looking, without being genuinely beautiful," and he supported this opinion with a few examples described in his masterful style. We too were surprised at the unusual physiognomy of the women here. Their faces are broad, heavy-boned, and rounded but without mongoloid cast; they are not beautiful in our sense but they have a pleasing regularity. The men have sharply cut features and a truly noble mien stamped by the desert.

We have already reported elsewhere on the life here (137, 149). Themselves living in absolute poverty, but always willing to aid others, happy and without strong inhibitions, completely natural, these people taught us the simple but basic truth that happiness is possible in renunciation rather than possession.

E. Karimabad to Birdjand via Khusp

We broke camp at Karimabad on 18 January and set out northward through the loam clod kavir. The heavy rain of the day before had washed away most of the salt efflorescences, but traces still lay like frost on the rims of the imprints of the camels' hooves, where it had not been able to percolate down into the kavir soil. Walking is difficult on the extremely soft ground. After 1.5 km we cross the Shur-Rud; it contains a little water now. Where the path branches off to the right toward the village Amberi we continue on a course of 20° directly toward the pass of Hamund, a broad col between the Hassardar chain in the west and the Shah-Kuh and its spurs to the east. Ahead on the left is the village Aliabad, half buried in sand. In the crusty, upturned white salt of the cloddy loam kavir even the saltwort is withered.

After 6 km the path leads across a sandy floor where traveling is faster. We cross ruined qanats and pass a number of bands. Saltwort grows on deflation hills which are about 1/2 m high; on the 10 April trip we also saw young tamarisk. But it turns out that the ground here still consists of soft kavir soil which had been blown over with sand. Passing to the right of the village Sar-i-Chah we cross a qanat bearing water from the pediment of the Shah-Kuh; after 7.5 km we cross a stream coming from the right with artemisia and saltwort growing in its bed. The

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ground is often covered now with coarse rock debris; as we proceed uphill it gradually turns to the familiar pavement. The deflation hills and kavir formations are now behind us. In their place is a firm deflated surface of andesite and eruptives with large hornblende crystals. At the same time the vegetation has become more abundant; in the spring small blades of grass and fresh weeds grow here, constituting pasturage "fat" enough for the easily satisfied sheep, which are allowed to graze without attendance because they always return to the spring in the evening to drink.

It is interesting to note how the clod kavir soil merges to the firm ground of the slope. In the deepest and moistest spots the upturned loam clods give the surface the appearance of a field plowed a few weeks earlier. The effects of the wind are evidenced by the angular edges of the clods and by the gruss, which was transported here by the wind and held fast by the moistness of the soil. It is interesting to note that the clods form even in the caravan path which, of course, is tramped down constantly. Even the thick layer of powdered salt which covers the cloddy kavir of Sar-i-Chah can be washed away by one day's heavy rain; traces remain only along the ribs formed by the hoofprints.

The following area, which is somewhat higher and drier, is characterized by deflation hills with low rounded peaks resembling pock marks; in the areas between these lie loam or salty sand. The further we proceed up the gentle slope, the more commonly we encounter coarser rock debris; it gradually merges to a deflated rock pavement.

Here we come upon the first bands, small dikes led from the foot of the mountain to fallow fields, apparently with the purpose

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of storing up in the fields the moisture of an entire year, as in dry farming. Note that such methods are used even at an elevation of 1,300 m! The observations that have been made on nonirrigated farming in Iran (12) certainly need to be reconsidered so far as this particular area is concerned.

The deposition of the dark green gravel and the coarse rock debris on the brown loam kavir can only be explained by the assumption that the process of kavir formation (which is still progressing today) was once interrupted by a period of heavy precipitation, during which it was possible for this material to be transported here. In the soil profile the brown loam kavir constitutes only a residual remnant. We shall encounter other profiles with such remnants.

After 12 km we reach the Hauz-i-Mehmed-Shah. The Shah-Kuh with its sharp pinnacle dominates the scene. In front of it is a lower chain with greenish red mineral bands. At the foot of this chain is the largish village Hamatsh. Before us to the left are the Hesardah Mountains, notably lower and with frequent saw-toothed, uniformly high ridge forms. Since there is no apparent stratification we assume that, like the Shah-Kuh, they are constituted of eruptives. At the foot of the Hesardah Mountains are the small villages Sidu, Hesardeh, and Feisu.

In the plain, which now slopes uphill, is a slowly downcutting stream with tributaries from both mountain chains. The fact that the pebbles in their beds are exclusively eruptives confirms our theory on the nature of the Hesardah Mountains. Along the path we break specimens (Rock Sample CXI) of eruptives rich in hornblende; marmorized limestones are interbedded. Following the stream bed,

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with its isolated but rather tall tamarisk, we pass a hauz and then ascend across an area dissected by deeply incised gullies. The diagonally running channels grow deeper and deeper as we proceed toward the pass. The latter, situated between 2 such channels and unevenly constructed, is in the process of being dissected and pushed back by the superior erosional power of the northward flowing Rud-i-Gaz. The flat areas in the mountains which flank it on either side can only be described as benches, but contrary to the present-day upper drainage they slope southward. We now follow the Rud-i-Gaz across a flattening plain paved with dark gray gruss and strewn with sand; on the right side of the river is a broad gravel terrace. Where the river bends toward Abbasabad we switch to the bed of a tributary and continue toward Hamund.

On 8 February we journeyed to the same pass from Hassardar, a village with 16 farms in the upper part and 2 in the lower part; the village is half empty. Its few fields are planted to wheat and cotton and its orchards to pomegranates. The path along the 8 km from the village to the hauz below the pass leads constantly uphill and down, through hills of medium height and across numerous stream beds. We note vertical tuffs striking 150°, veins running east-west at an acute angle to the direction of the drainage, and quartz veins running north-south. The path leads through eruptives or pure tuffs or tuffs with lapilli. Kavir formations appear commonly. An unusual sight are the isolated rocks twice the size of a human head lying on broad loam kavir. For the most part however the soft ground is covered with a layer of dark green gravel. The vegetation is of the usual type.

Passing Hamund and the road to Majan, we set out to cross the Majan Plain again, this time 15 km further to the west. With considerable curiosity as to what sort of landscape we shall find here, we move down a stream bed, which soon turns to the left to follow the general slope of the terrain. We therefore leave it and travel along short but sharp ups and downs through a hilly area, not quite one km across, built up of eruptives and tuffs. Bare peaks and occasional slopes covered with transported sand bear witness to the strong winds. We stand next before a gently sloping plain flanked on the right by a chain of hills. The streams in the plain have cut through these hills, where they apparently find so much erosion work that they choke the upper courses of their beds with sand and are no longer able to cut down. They do not begin to cut down unhindered until we have crossed a small rise in the terrain and left the hills behind us to the left. We pass 2 higher isolated hills and cross a gently sloping semidesert with sparse artemisia which is covered in stretches with transported sand. Then 11 km beyond Hamund we reach a broad gravelly stream -- probably the continuation of the Qal'eh-Lak-Tshapan we crossed in Section C. We cross numerous other stream beds (undoubtedly also continuations of streams described in Section C) which contain primarily gravel. Since gravel did not appear to be predominant in the stretch between Hamund and Majan, it is probable that gravels or conglomerates lie between the 2 routes as continuations of the formations observed near Hamund and that they supply the material that covers the bottoms of these streams. The extensive bench land [Landterrasse] is additional confirmation of this thesis. The further we proceed downhill, the more commonly the salt efflorescences appear. A 2-m deep

stream bed which we cross at the 12 km mark is white with salt, probably indicating that in spite of the heavy precipitation here it contains no water throughout the half year of winter.

We now drive across an almost smooth plain paved with gruss. On the right are 2 chains of hills which deflect the streams from the Shah-Kuh. Before us is a single inselberg with a cross-shaped "Kanzel" as summit. It is constituted of red porphyritic eruptives (Rock Sample IC). The surface of this semidesert with its sparse vegetation is paved with egg size fragments of the same rock. Soon it is covered with loose sand and salt efflorescences, but near the center of the depression the sand, crusted and permeated with salt, lies lighter.

After 20 km we reach 3 small rivers containing salty water, apparently lateral channels of the Karedjan; soon thereafter we reach the bank of the Karedjan itself. The shallow, strongly salt water tumbles with amazing speed over tiny islands with low growths of tamarisk; these plants, which also grow on the bank, bear reddish pink blooms at this time of year (10 April). The water empties into a large white salt kavir and then pursues its way toward the desert.

We drive up the gradual slope of the other side of the depression across an extremely soft salt kavir completely barren of vegetation, where even the caravan path is firm only in places. Soon however we come to a sandy stream bed which has cut a firm path through the kavir. The latter begins to disappear; as soon as it has been reduced to strips, vegetation begins to appear again. We travel gradually uphill for 5 km and then cross 3 salt streams with steep banks cut deep into tuffs. We pass mushroom rocks and

small table mountains constituted of horizontal lava caps on tuffs, and move over low, randomly scattered hills with relatively dense growths of artemisia toward a high point 10 km beyond and 60 m above the Karedjan River.

What a great difference between this route and the route we took just a few kilometers to the east across this same depression! Whereas the area around Majan is densely populated, here, except for a few abandoned water reservoirs, we encountered no sign of civilization. The salt kavir, which forms here because of the abundance of salt and in spite of the heavy precipitation, is like the Lut proper, completely barren of vegetation. And please note that this is only a few kilometers from the fertile island of Majan. Such differences are possible only on the edge of the desert, where the slightest change in the geographical conditions can produce great contrasts.

As we move slowly downhill along a stream bed we are surprised to come upon a gravel terrace one km long, made up for the most part of quartz the size of one's fist. Further on, where the gravel has been eroded away, the ledge can still be easily traced at a height of 8 m. The path leads across a gently rolling, diagonally transected desert steppe. After 16 km we come to a low hill with a small mosque from which it is possible to look out over Khusp, 6 km away. We head downhill toward the city, moving across gravel-like quartz and through badly withered vegetation.

We pass the graveyard of Khusp near a small retaining dike and soon thereafter reach the steep bank of a river which has cut down 14 m through gravel and clay into the tuffs. The water is slightly salty; near the edge grow low reeds in addition to the

usual vegetation. Without stopping at Khusp we set out to the northeast on the road to Birdjand across pea-size quartz which forms a deflated surface over the underlying gravel. The slopes and even the usually firm bare peaks -- made up here of quartz and eruptives -- are so exceptionally soft that we decide to make an excavation. The surface pavement at this point is made up of the hornblendic eruptives of the Kuh-i-Rich; underneath is a powdery white sand which beyond 15 cm begins to show loose gypsum crystals. We dig 80 cm deep without reaching the end of this sand.

We pass wheat fields and orchards of blossoming fruit trees until we reach the village Sarpan. To the left along the river is an almost unbroken string of villages, but we move again into a desert-like steppe with no vegetation except saltwort and khar (Alhagi Desv). But 3 km beyond the village the floor, on which the fragments of hornblendic eruptives grow ever more common, once again bears desert plants 4 cm high. Across from Tagab (see page 278) we cross 2 streams 7 to 8 m deep and come to a hill where we discover an important exposure. We shall describe it later.

Two kilometers further, another village appears on the left side of the river. We cross more relatively deep stream beds leading from the mountains; a few of them still bear water. The rocky pavement in their vicinity is made up of coarse material with fragments often as large as one's head. These are obviously debris from the stream, deposited during flood stages; but it is surprising that the current could have cast such large pieces up so high. Observing the streams along the pediment we near the village Deh-Nou, 5 km from Birdjand, then pass through the familiar Husainabad and Amirabad to reach our goal.

The agricultural picture on this stretch between Hamund and Khusp is startlingly different from what we encountered a dozen kilometers to the east between the Bakaran and Kuh-i-Shah Mountains. Here, as in the Lut Desert, it is apparent that water alone is not sufficient for cultivation, for the fields must also be free of salt if they are to yield well. Particularly important morphologically is the intensity of the chemical weathering here. East of Khusp the ground was so soft that the wheels of the car sank into the loose sand, despite the fact that it was paved with fragments of eruptives and quartzite, usually the size of an egg. In our excavating we were not able to reach the bedrock, but, judging by the sandy mantle rock, it is probably constituted of a fine-grained sandstone.

In our observations we have already frequently referred to chemical weathering. Here for the first time we encountered in a well defined layer, almost 25 cm beneath the surface, a concentration of gypsum crystals. This concentration is apparently formed in an "equilibrium horizon" at the point where the effect of the ground water rising under capillary attraction and that the rain water percolating down hold each other in balance. The rising ground water brings up the mineral solutions and in the process of evaporating deposits them in layers near the surface or -- in the case of the efflorescences -- at the surface. The rain water, on the other hand, dissolves the minerals of the uppermost layers and as it percolates down is absorbed by the soil; in the process it deposits the minerals or precipitates them out. Such observations have been made previously by Blanck and Passarge (16), Kaiser (90), Mortensen (104), and others.

Thus it is clear why the rocky pavement of the top surface shows so little effect of chemical weathering; on the other hand it is subject to a much greater extent to the various processes of mechanical weathering. It protects the underlying sand, salty sand and loose gypsum from deflation. Where there are breaks in the pavement, i.e., where individual parts of the protective rock cover have been weathered away, the break is crusted over by salt or gypsum, or, occasionally, by limestone or sinter, which has been separated out. In our overland journey I was constantly on the lookout for dust horizons -- in the interest of our own safety -- but found only one such (under a deflated surface in the process of disintegration: see Volume I, pages 74-75). Apparently such stages of disintegration do not exist long because the dust lying in the open is blown away by storms; therefore they are rare.

Of course zones of intensive chemical weathering are possible only where ground water can rise under capillary attraction, namely where in addition to salt, the "heart" of desert weathering, there is also considerable precipitation. I should like to repeat in this connection that in our travels in the Lut and the areas around its edge we preferred to drive in the stream beds, because in spite their uneveness they offer the best support; in the level desert we often sank in.

We are convinced that the intensity of chemical weathering in arid areas is still commonly underrated in spite of the testimony of reliable researchers. We shall refer to this again.

The second important complex consists of the terraces and benches. In the valleys through which the 2 mountain ranges are drained they occur in clear-cut form. The lowest is usually still

in the form a gravel terrace while the upper 2 appear as bench levels embedded in a trough, which, to be sure, is recognizable as such only in places.

This apparently simple scheme is complicated by the sands, sandstones, and conglomerates which were undoubtedly deposited in relatively recent times. Moreover they are bedded horizontally for the most part, although the area has been subjected to an extraordinary degree to tectonic disturbances. We cannot present a unified picture until we have completed the discussion of all the routes, but we must deal here with the peculiar characteristics of these sedimentary deposits.

We have already brought out the facts that there are 2 alluvial cones (900-950 m) of different ages at the Kuh-Bakhtu, and that 10 m of gravel and clay are bedded over tuffs near the Khusp graveyard (1,305 m). East of Khusp, across the river from Tagab, which is situated on the right bank, we made an unusual discovery: an exposure with an underlying bed of reddish, only barely consistent clay shale striking east-west and slightly folded; in the joints quartz bands have formed. This rock then has already been subjected to orogenic disturbances, but overlying it are undisturbed, reddish brown conglomerates 30 cm thick; and overlying these are ocker-colored, fine-grained conglomerates, the individual fragments of which are so little rounded that one could mistake them for breccia if they were not completely undisturbed and so well stratified.

In order for clays to have been deposited, the Birdjand Valley must have been filled with still water prior to the most recent folding.

This deposition was followed by folding and then, no doubt, by a period of denudation, for the clays could hardly have formed to clay shales -- even such loose ones -- without being covered by an overlying bed (which subsequently fell victim to the processes of denudation).

Then came the deposition of sands, gravels, and detritus which were compacted to form the reddish brown conglomerates. Apparently this period of sedimentation was followed by still another period of denudation; for entirely aside from the different character and coloration of the overlying ocker-colored, fine-grained conglomerates, the angular character of the coarse individual fragments would be conceivable only as the result of processes in an extremely arid climate. In the heart of the Lut we frequently observed similar fragments, the lighter ones of which had been transported by the wind. Nor can these be fanglomerates from a talus fan, for the granular composition is uniform. The debris which is forming today or was recently formed on the surface around the exposure is completely different in character from these fine-grained conglomerates. It is therefore justifiable to assume that since the formation of the topmost horizon of our exposure a change must have taken place in the natural conditions. It would surely be a mistake to work up a development theory on the basis of this one discovery, but it should be borne in mind when the time comes to reduce all our observations to a common denominator (Route V).

At the same elevation as the beds we have just discussed (1,415 m) lie the half-compacted conglomerates of Hamund. Apparently formed as terraces of the stream which flows north or

northwest from Hamund whenever it rains, they stand in sharp contrast to the gravel terrace to be seen 3 km south of Hamund on the left bank of the Rud-i-Gaz: the latter is obviously the much younger of the 2. Since our dark brown conglomerates, so far as we were able to determine, can be observed for great distances beyond the stream, and, as we have already brought out, appear on the basis of the gravel in the nearby streams also to exist further east, we must conclude that they are not terraces of this stream but depositions belonging with the conglomerates and sandstones which we observed from the edge of the Majan Plain (1,460-70 m) to the Kuh-Givshad, where they are apparently younger than the eruptives of the crater (which is itself young).

All of these depositions indicate that the most recent time here was characterized by important periods of sedimentation. At the present time it is impossible to order all of these depositions in the time scale and, with a few exceptions, to put them in their exact relationship to each other; but all of them have this in common, that they are all in the undisturbed condition of their original stratification. Exceptions to this rule occur only in isolated spots, namely south of Hurmuk (Volume I, page 37), to the east of Birdjand, and in certain places along Routes IV and V. These recent deposits also have in common the fact that they consist of sands, conglomerates, and clays, but with the latter occurring, so far as we were able to determine, only in the undermost beds.

Finally it should be remembered that, allowing for the present-day level differences, they correspond in elevation, that is, that they belong together; they must have been deposited by

heavy water-bearing streams or heavy sheet floods in a terrain sloping as the present one does. The gravel deposits at the Kuh-Bakhtu lie notably lower than those in the fringe areas, but this is in accordance with the general characteristics of the Lut.

Thus Route II has led to a few conclusions about the Bakaran and Shah-Kuh Mountains. It provides information on the gravel deposits and on loess, as well as on the economic geography on the edge of the uninhabitable Lut.

ROUTE III. INSIDE THE LUT

(see Sketches 10-17)

A. To the Gateway of the Lut

Between 1 and 6 April 1858 Khanikoff journeyed with a great caravan of 55 persons and 42 camels and horses from Karimabad (Village of the Kerim) to Khabis (Shah-Dat). We are indebted to his report (53, pages 402-420) for our knowledge of this part of the Lut. Therefore at the time of our visit 74 years had passed without a single European having made a report on this stretch. We should always bear this in mind when we find Khanikoff's report unsatisfactory, even if he was accompanied by a whole staff of scholars. Though some of his observations may be incorrect, they have nevertheless enabled geographers to put together something of a picture of an area on which there was previously no information whatsoever aside from that supplied by a few Arab geographers. Then too, it is likely that he was not allowed to publish some of his observations, since his trip was made during the Russian-British quarrel over the Indian Glacis. The British also published from their observations only those parts that pleased them.

We travel southward from Karimabad. Having left the fields and djubs behind us, we come upon a stream bed between broad areas of salt efflorescences; at this time of year, the rainy season, it contains salty water. We come next to a smooth gently sloping plain full of sandy kavir formations between granular salt efflorescences; among the saltwort bushes are abandoned qanats. Nearer the village Sar-Chah-Shur, where the stream cuts deeper and the terrain becomes less monotonous, we come upon an outcrop of intensively weathered phyllites. Numerous abandoned qanats leading to the village bear witness to the difficult struggle for existence here; they were probably abandoned because the water dried up or became too salty.

Beyond the village with its 26 primitive quadrangular houses we enter a rolling terrain with small hills of eruptive rock. Drift sand lies at the foot of these hills and also in the insignificant water channels. The half-meter high deflation hills indicate that the prevailing winds are from the northwest; as vegetation these deflation hills bear various halophytes and tamarisk from which all the valuable wood has been removed. Beyond this area we come to a salt-white flat with strips of sand and a few halophytes. A small stream coming from the left, which contained a little water on both of our visits (13 January and 20 March), discharges into this flat. Its banks are soft and white with salt. Sharply dipping phyllite striking approximately north-south runs in small walls through the erosion channels. Our smooth caravan path, covered with gruss or a rock pavement consisting of egg-size clastics leads toward a few low hills flanked by mountain chains. After 12 km we come to a hauz; in the surrounding gruss-strewn ground are rich growths (in March) of tamarisk, saltwort, saxaul, shepherd's purse, and even a little grass. The neighboring hills

have a greenish cast, probably caused by the malachite and serpentine already noted farther to the east (page 52). The ground turns to a dark gray, and as we move along a barren stream bed into the hilly area we observe phyllites striking 40-50° with dip ranging from 60° southwest to vertical. These are run through with quartz veins which can be traced for great distances in the form of weathered-out elongated ridges. At the high point on a broad ridge between the chains of hills there are scrub vegetation and strips of effloresced salt -- on the higher spots rather than in the depressions as is usually the case. A second hauz is located here; its water may be a factor in the unusual vegetation picture.

Moving downhill in a shallow stream bed we come upon residual eruptive rock in the form of diagonal walls striking east-west. The vegetation is richly developed, especially the numerous desert gourds. The stream runs too far northward for our purposes, so we turn back to the left to the caravan path. We cross a small rolling area and then move downstream in a broad stream bed. An eruptive rock (Rock Sample LXII) is exposed in its steep (up to 10 m high) right bank. Where it occurs on the deflated surface or in the talus accumulations of the nearby hills it has been weathered to a deep black. Beyond the third hauz the rolling plain slopes off to the west. Between the patches of dark fine gravel and gruss there is good pasturage and saxaul bushes from which the ligneous material has been removed; at the higher levels are the usual bare areas paved with clastics as large as one's hand. We pass the fourth hauz and cross a broad stream bed with the cut bank on the right and then turn off to a camp of 5 black tents, where on 20 March we pitch our own Camp 46.

In these tents lived some 30 people from Sar-Chah-Shur and Aliabad who had already "wendered into spring" with their cattle to live carefree during this, the most beautiful time of the year. Most of them had formerly owned caravans running between Meshed and Zahidan, but today the traffic is limited to the stretch between Birdjand and Shah-Dat, where wheat, pumpkin seeds, beans, and peas are bartered for citrus fruits. We spoke with 3 brothers who still had 23 camels in service -- which was regarded as a considerable number.

The young lambs are kept overnight in small earthen grottoes and taken out early in the morning to the mothers which have been brought to camp to drink and to be milked. The people occupy themselves with cooking down milk and making cheese until the middle of May when the pasturage dries up. At that time some go on into the mountains with the herds while others return to the villages to devote themselves to agriculture. The area is known as "Atesh Kerdan" (Fire Making). This was also reported by Khanikoff (93).

Here 30 km west of Karimabad and 70-80 m lower, the temperatures are markedly more extreme. At 1700 hours the reading was 14° C -- as high as at midday in Karimabad -- and at 2100 hours 8°, the low was 2°. On 21 March at 0700 hours the temperature was 4° C but by 1100 hours it had climbed to 16°. On 20 March there was a gentle wind from the northwest which died out at 1930 hours.

Taking leave of these cheerful people we set out across a broad depression with several stream beds. The ground is covered with gray gruss, and frequently also exhibits brown to reddish loam and clay. The western slope of the depression has a clearly visible

terrace with growths of tamarisk and saltwort. We now move downhill into a second depression with broad, sandy stream beds; there are long strips of sand in the deeper places. Small hills are covered with gruss. The tamarisk, as usual, is restricted to the lower spots. The bare rocky areas constitute an hammada with egg-size rock fragments.

The next depression consists of loam kavir. The stream bed running through it contains rather dry, loose sand. This depression is followed by a dissected terrain with numerous salt efflorescences. The rocky pavement on the higher areas is made up of egg-size clastics. We encounter sand in large quantities, always with salt efflorescences, in which halophytes grow. Another 7 km and we come to a salt kavir 50 m broad with a sandy stream bed along its edge overgrown with tamarisk. The numerous steeply cut channels in the alkaline soil bear witness to intensive erosion. We cross a ridge and come upon extensive sand kavirs with stream beds incised 2 m deep containing abundant tamarisk and a little saxaul. The barren ridges are covered with palm-size fragments of obsidian or with tuffs discordantly overlain by young conglomerates or gravel. These streams supply the water for the warm spring at Ambar (see page 61). They also nourish rich growths of reeds of the usual sort; in the deeper spots of the surrounding area are extensive tracts of thick salt kavir. Since this is the last water and wood source along the stretch to Shah-Dat, we replenish our supply.

In the southeast is the Kuh-i-Shah, about which we shall learn more later. Before it lies a chain which includes the mountains of Qal'eh-Seri (Gold Castle) more than 20 km away (see page

206 ff). The hills which trend from this chain directly toward our present position are towered over by a few low but outstanding mountains including the Pelassi and Stalnik Chains. Two kilometers away at 167° is the hill Karaul-Chan-i-Ambar (Guardhouse of the Fountain) and at 53° the Mikh-Ambar (Peak at the Fountain). Even the sharp peak of the Garm-Ab (Warm Water) can be sighted at 23°.

It would be instructive to compare the complex phenomena of these 5 depressions we have just crossed. They constitute a series of steps of 10-20 m each, descending more or less uniformly to the lowest one at Ambar. The highest one has gruss, loam, and clay in the soil; the second has patches of salt in the lower spots; the third consists of a loam kavir cut by a sandy stream bed; the fourth is covered with a sand kavir bounded by a sandy stream bed; and the last, the one at Ambar, is covered by a salt kavir with an incised stream bed.

This regularity suggests that the changes may be determined by the decrease in precipitation at the lower levels, i.e., that at the higher levels the salt is washed away by the rain, but further down where it is brought to the surface by water under capillary attraction there is not sufficient precipitation to wash it away. But the slight difference in elevation is not great enough in itself to effect such a change, not even here on the edge of the desert, where small variations in the geographical conditions often do bring about great differences in the landscape. Therefore if the difference in rainfall will not suffice to explain the change, we must look for the explanation in the rock itself. This we did, in part, in our observations on the

gravel of Ambar. The glassy, hard obsidian should also be considered as a possible cause.

Let us imagine this area to be in one of our uplands. Noncrystalline, powdery salt is to be found there, sometimes in sand, sometimes in loamy dust, wherever we could reasonably expect to find ground water outlets such as cienagas /Nassgallen/, meadow seepage /Wiesenfeuchte/, or even springs. With just a little imagination this analogy can give us excellent insights into the origins of salt efflorescences, so that it is difficult to understand why such highly dubious hypotheses on the subject are to be found in the literature. Excepting certain special deposits, we may state that in general salt efflorescences result when salt is brought to the surface in solution by water under capillary attraction and left there "effloresced" after the water has evaporated.

These efflorescences are characteristic of the desert fringe areas. They do not appear at all in the completely arid heart of the desert, because the rising water evaporates before it reaches the surface. Mortensen made this same observation (103).

The first few kilometers of the caravan path beyond Ambar were described in some detail in Route I. We confirm the identification made then of 2 levels of peneplanation. But this time we drive northward around the kavir, pass 2 hills with volcanic glass, and then drive into the river bed in which we identified the rock terraces on the first visit. It can be seen on both sides of the river at a height of 15 m. We are surprised to note that the river bed runs through bedrock. We leave it where it turns to the right, 10 km beyond Ambar. After crossing a stream bed we drive gradually

uphill between hills with gray gruss and a little vegetation. Beyond the high point is a slightly furrowed plain sloping off westward; it is flanked in the south, and partly in the west too, by 2 mountain chains. The stream and the caravan path lead toward a point where these chains come together at right angles to form a typical pass: the gateway to the Lut. (Khanikoff knew it by the name Gueloui-Saandagher, i.e., Gorge of the Merchants; the English map gives it the name Galu-Tagaz but with a question mark; the latter might be translated roughly as Gorge of the Haloxylon ammodendron.) Where we step out onto this plain the hills, which are covered with mountain waste (eruptives), become lower and flatter. We take a specimen of a dike rock (Rock Sample LXIV) in dark eruptive; on the right are remnants of the gravel and conglomerates mentioned above. The plain is soon covered with fine waste from the outcropping rock; but the stream bed still contains salt efflorescences and a little vegetation. We enter the gateway itself, which has 3 terraces, and break samples of a dark eruptive on the left (Rock Sample LXV) and a dark green eruptive on the right (Rock Sample LXVI), both of which exhibit a deep black weathered crust. From here we have a clear view before ourselves of the Lut with the inselbergs, most of which are already familiar to us. One could say that the gateway is like a theater with a view into a boundless region stretching away to the southwest. Before us lies our goal for the following day, for we are now to leave the fringe areas and rush on into the heart of the desert.

We shall attempt here to summarize the observations made on the stretch between Karimabad and the gateway to the Lut.

We encounter here once again the residual mountains made up of mica schists striking 160°, of serpentine with amphibolites, and of phyllites which strike sometimes north-south, sometimes east-west, sometimes 40 to 50°. Since the dip is at times vertical and at times, more moderate, and since there is sharp folding, we know that we are dealing here with the continuation of the fold mountains which we encountered repeatedly to the south of this route. We also established the presence of effusions of great extent, including volcanic glass, and fissure fillings striking east-west.

Near the edge of the desert are 2 levels of peneplanation, the lower one of which connects numerous peaks, the upper one (50 m higher) more flat areas than peaks. There are rock terraces and gravel terraces; at the gateway itself one can see clearly a lower gravel terrace with 2 higher benches, which is in accordance with observations made elsewhere.

Apparently the area is occasionally subjected to violent precipitation. This is evidenced by the deep erosion channels, by the visible presence of the bedrock in the dry river beds, and by the rock terraces (we assume these to be gravel terraces from which the gravel has been washed away). The presence of the bedrock in the river beds tends to justify the assumption that the basin of the Lut has sunk continuously; the abrupt break between mountains and basin probably indicates the presence of a marginal fault in the east. The broad salt kavir areas which occur so frequently are probably to be accounted for by abundant rainfall. They even appear on the interstream areas which we have described elsewhere as "barren heights."* Because the precipitation has created springs

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and a semidesert vegetation, the natives bring their herds here in the spring to graze. But the wind -- chiefly the northwest wind -- is also an important morphological factor. The south winds appear to have only secondary effects.

B. To the Heart of the Desert

Only a short distance beyond the gateway the stream feathers out in the floor of the plain, which is covered with detritus (further on with gruss) and stocked with sparse saltwort. We move along a new stream bed toward a typical, hat-shaped inselberg; the bed contains smallish rock fragments, including the familiar dark green eruptive (Rock Sample LXVII). We move across the plain in the direction of the pediment of the Kuh-Bakhtu, using a dry river bed as a "highway." Soon, however, it becomes so deep that we have to leave it, for it is dangerous to be caught in such a gully at a time of year when a storm may break at any moment. Four kilometers from the mountain a rich vegetation begins to appear on the alluvial cone; up to this point the vegetation had been restricted to the stream beds. The intensively dissected alluvial cone is covered with rock rubble with fragments up to the size of a child's head. This is the cone on which we pitched our camp in the vicinity of the mountain from 21 to 23 March (Route I).

In order to get back to the caravan path we seek a way among the 3 smaller inselbergs to the west of the Bakhtu. There is room enough between them, but we were afraid that the deeply incised streams might block passage. These streams, richly overgrown with saxaul, desert plants, shepherd's purse, and forget-me-nots, accompany us down the alluvial cone until we find a pass between the 2 southernmost inselbergs. We had expected to find a

single stream here, but in spite of the narrowness of the passage there are numerous streams and the depression is dissected haphazardly; many blocks the size of one's head indicate the force of the water and the rich vegetation testifies to the thorough ground saturation. But within 500 m the ground is mostly sandy and the pebbles no larger than one's hand; the vegetation becomes sparse and soon disappears altogether. The coarser pebbles have been rolled here from another side of the spurs of the Bakhtu. Apparently a part of the streams described in Route I collected in a main channel, but then broke out of the banks and subdivided in for lack of transport lightening (in accordance with the transport formula I have developed elsewhere: see 145).

After 7 km we come again to the caravan path leading to the southwest. Because it is hardly visible in the smooth gruss, it has been marked off with stone markers. Five kilometers further the deflated surface consists either of head-size boulders with gruss, or of smaller rock fragments with fine, loamy, yellow gruss. But here it is strikingly thin, so that the sand and loam of the subsurface often breaks through. A compound stream, actually only a ribbon of bright bare sand, runs on our right; apparently a continuation of the stream from the peak of the Bakhtu, it appears to unite in itself all the streams of the area. When we cross it we see that it is no more than a shallow trough; in places it has a cut bank on the right, but no more than 50 cm high. Obviously it does not contain water very often, in any case, not during every rainy season; otherwise the erosion rim would be clear-cut.

After we have climbed a small rise in the terrain we find the deflated surface made up of small fragments at most no larger

than egg-size. In many places there is sand and gypsum covered but poorly by a layer of gruss up to 2 cm thick. After 4 km a 5-m broad, 20-cm deep stream bed coming from behind us from the right on a course of 160° crosses our path (130°), before us to the left. Shortly thereafter we come to a similar stream with 4 saltwort bushes on its edge. A third stream bed, which we drive down, has a 15 cm cut bank on the right of sand clods cemented by salt; it turns to the left and disappears in the flat terrain. We now drive over a flat surface of gruss which covers the salty sand and loam imperfectly. We cross a broad, shallow stream bed with 7-8 halophytes, later several smaller ones which are actually only slightly depressed ribbons of sand; only one of them has a cut bank 15 cm high on the right. Apparently these are all branches of the compound stream mentioned above. Later we encounter a stream coming from behind us running from left to right: apparently the slope of the terrain has changed slightly without our noticing, probably as a result of deflation or deposition by the streams.

In the direction of the Kuh-i-Surkh, which we sight at 213° after having traveled 20 km along the caravan path, are a small chain of hills and a large pointed cone. In the west are several smaller hills disassociated from the Kuh-i-Murgh and a chain trending north-south. We move directly toward the Kuh-i-Bala-Hauz (Mountain of the Upper Cistern); a few large and small inselbergs rise above the basin of the Lut here.

Once again the smooth desert floor is covered with the layer of gruss with gaps here and there; the fragments are never larger than pea-size. The same picture is predominant for another 6 km,

but the gruss layer becomes thicker as we approach the Kuh-i-Bala-Hauz, a 3-peaked hill about 30 m high. We turn off the caravan path and drive across an extremely soft floor to the hauz, which is constructed for the most part of granite; even 74 years ago it was in ruins. In the hill itself we break a sample from a fresh fracture plane of hornblende granite porphyry (Rock Sample LXXII). The appearance of granite here explains the deflated surface of gruss. We drive around the hill, noting similar conditions. We lose the path and find it again -- after wandering around for 10 km -- near 2 other ruined hauzes not far from the point where we left it. The guides tell us that Shah Abbas had a well sunk here 100 sar (about 100 m) deep without finding anything but ashes, because, they say, in the Lut the earth is scorched from within -- a good indication of the intensity of the chemical weathering which has reduced the soil here to dust.

In Camp 47 on the Kuh-Bakhtu there were rich growths of saltwort of considerable height, and flowers grew in the stream beds or on their moist banks. Our diary mentions forget-me-nots, shepherd's purse, mountain ash, and "Apollofalter." Here, 20 km beyond Camp 47, the vegetation is reduced to isolated plants growing in the more favorable spots in the stream beds -- which are themselves growing less and less common; there is no vegetation whatsoever on the broad areas between the streams. The stream which we cross at an elevation of 610 m at the fiftieth kilometer bears in its bed saltwort bushes growing at intervals of 20 m, but by the twenty-seventh [sic] kilometer there is unbroken desert. At Bala-Hauz (sixty-sixth kilometer, 570 m elevation) a little vegetation appears again, but from that point on, every trace of vegetation disappears. Khanikoff, who traveled this stretch only

a few days later during the same season, made similar observations. Between the Kuh-Bakhtu and the Kuh-i-Bala-Hauz he found a few growths of saltwort and caligonum, but beyond the Kuh-i-Bala-Hauz "le désert avait pris completèment son caractère de terre maudite, comme l'appellent les indigènes. Pas le moindre brin d'herbe, aucun aigne de vie animale n'egayait la vue." (93, page 170). The English map also indicates the "limit of vegetation" here.

Beyond this point the desert changes in character. The elevation along the caravan path had dropped by 300 m between the Bakhtu and here, but from here to the Khushk-Rud it remains almost constant. The floor also changes. At first we drive over firm sandy loam and small upturned clay clods where saltwort still grows on isolated hillocks in the barely distinguishable sand ribbons of the stream beds; but 2 km beyond the Bala-Hauz salty loam in the form of upturned clods is predominant; here and there coarse gravel is strewn over the loam or piled into strips by the wind. The deep imprints of the camel hooves indicate that the ground was thoroughly wet not so long ago. Soon the gravel disappears leaving the loam clods absolutely predominant. One is struck by the absence of the familiar salt efflorescences. After 5 km we leave the stream bed where the firm sand had made for easy driving, and seek a path through the uneven loam clods. The path, which soon becomes smoother and firmer again, follows the stream beds wherever possible, but even there the thin clay is thrown up in clods. Outside the streams the ground is so soft that we sink in almost 10 cm; therefore we keep at least 2 wheels on the hard surface formed by the camel prints along the caravan path. Nine kilometers beyond the Bala-Hauz a long low ridge, completely covered with rubble, runs off to the right from the path; the gravel

cover is thicker and the path smoother and broader, but the nearby surface is still quite soft. Before us is a chain of hills trending east-west which we have been expecting for the last 2.5 km because of the increasing hardness of the ground. There is a slight rise in the terrain, and the gravel, with hand-size pieces of quartz, begins to appear again in isolated patches. Near the hills the surface is completely covered with a thin layer of gravel, but contrary to expectation it becomes so soft that we are not able to drive very close to them. We pitch camp not far away in order to visit the westernmost and highest (about 100 m) of these hills. It is surrounded by several smaller heights almost buried in talus. On its peak small stones are laid out in the form of a circle, probably a burial ground from pre-Mohammedan times or a cache established by plundering Baluchi. We break a sample of quartzite; the other hills, their 12 peaks ranging off in almost perfect alignment (between 288 and 298°), are made up of the same material. Khanikoff called these hills Kellehper but there is no interpretation for such a name.

About 1.5 km away to the west is a large compound river running north-south called variously Khosh-Rud and Khuss-Rud by the guides; we were told that it collects all the water from Majan and Birdjand, i.e., the Shur-Rud and Karedjan Rivers. (On the English map this river is called Khushk-Rud, i.e., "River of the Castle," but this is probably an error for Chusk-Rud, "Dry River." Khanikoff calls it "Riviere de Khousse" in the belief that it was named after "Khousse," the city which we call Khusp on the basis of the map and the word of the inhabitants. See page 221.) Beyond the river the desert is perfectly flat as far as the Kuh-i-Murghab. Somewhat further south a small inselberg rises out of the rock debris.

A strong wind had been blowing steadily all day from NNW; the gusts were often so strong on the peaks of the small hills that we were almost knocked down. It was blowing in gusts at 1700 hours but then died down notably and blew as a steady breeze until 1900 hours. At 0300 hours (24 March) the sky was clear and there was no wind. The temperature (which in general rose notably with the decreasing elevation) rose from 12° C at 1000 hours to a high of 23°; at 1700 hours it was 22° in camp and at 1800 hours 18°; the low that night, to our surprise, was 4°. At 0600 hours it was 0° but when we broke camp at 1000 hours it had risen to 14°. The low was reached without any wind, an indication of the intensive radiation here in this flat desert. We never recorded such low temperatures in the higher areas on the edge of the Lut -- not even in January -- as we recorded here at the beginning of spring. Khanikoff reported a few rain drops here on 4 April (1858) accompanied by thunder over the western edge of the desert.

An excavation revealed a 20 to 30 cm layer of loose sand beneath the one cm thick covering of gruss. Beneath the sand we found a rock-hard horizon of salt with particles of loam (Rock Sample LXXIV).

Khanikoff formulates his impressions of the emptiness of the desert beautifully: "On assistait pour ainsi dire au commencement de l'agonie de notre planète" (93, page 177). But he was certainly mistaken in his notion that the sand forms these hills: the sand was transported here by the wind.

The areas beyond this point are characterized by an extraordinarily soft surface. Probably we entered onto a new rock when we passed Bala-Hauz, since the gruss gives way there to loam and

gravel. Unfortunately we did not dare drive near the ridge west of the path because of the danger of sinking in. This stretch to the Khushk-Rud might be almost impassable after a rain. The exceptional softness of the ground near the Kellehper Hills might be explained analogous to the observations made near the Bala-Hauz by the theory that chemical weathering is especially intensive there thanks to the water which runs down the slopes.

The Kellehper Hills themselves do not trend quite north-south. The fault fissures which do strike north-south are for the most part filled in with young eruptives. That these quartzites hills are the survivors of a forerunner which trended in more or less the same direction can only be surmised. In any case, the hills owe their existence to the greater resistance of the quartzite; unless the relief was determined by some special structural process we must assume that we are dealing here with erosion residuals.

The granite which we encounter along this part of the route may have begun as far back as Point 5, i.e., 5.5 km beyond Camp 17. The fanglomerates and angular rock fragments on the surface had already been replaced by gruss when we passed the inselbergs near the Kuh-Bakhtu -- the gruss which we recognized on the other side of Deh-Salm as the product of weathering on the granite; moreover, instead of the "rock barrens" which are characteristic of the higher spots on the interstream areas, in the Lut, we began to observe "gruss barrens," i.e., instead of a vegetation-free surface made up of various sized remnants of the country rock, we found a deflated surface covered with gruss and dotted here and there with boulders which have rolled down from the spurs of the Bakhtu.

No doubt the granite continues farther along the caravan path; for we always observed gruss, sand, and loam there. The rocky pavement of the surface was made up of gruss, gravel, and, less frequently, of larger rock fragments; usually it was full of holes, through which we could see sand or loam cemented by salts. The dry stream beds contained loose sand, remains of the quartz from the underlying granite. Four kilometers beyond the Bala-Hauz none of the components of the deflated surface were larger than bean-size.

The ground beyond the Bala-Hauz is also strewn with gravel and gruss. On occasion we noted hornblendes, which of course are not unknown in the granites of Eastern Iran (158). The surface does not become dense and free of holes until we reach the vicinity of the Kellehper Hills; it is therefore altogether possible that the granite extends to the quartzites of these hills. We should surmise that the especially soft ground which we found between the Bala-Hauz and the Kellehper Hills is determined by a special formation of the granite; we observed a similar condition on the other side of Deh-Salm.

Unfortunately we were not able to establish the borders or junctions of the granite. But if we regard it as the core of a denuded anticline, as geologists have done with the granites elsewhere in eastern Iran, then it would follow that the hard limestones of the Kuh-i-Surkh and the Kuh-i-Murgh are synclines, indicating a relief inversion. If one follows Gabriel's description, the hard gray limestones of the Murgh are probably the same as those of the Kuh-i-Surkh. To be sure, such conjectures remain hypothetical. But they proceed from the repeatedly established

fact that the parts of the Lut visited so far represent residual fold mountains with numerous volcanic effusions.

For days we move along the caravan path across a smooth but soft surface covered in places with gruss, but usually with an imperfect gravel pavement with rock fragments up to the size of one's hand. Four kilometers beyond the Kellehper Hills the path crosses the Khushk-Rud at a point where it makes a small loop to the east. Completely lacking in vegetation, the 50-m broad bed contains smooth sand and small upturned loam clods, with gravel up to egg-size on the edges. There is a sloping bank on the left and a cut bank on the right 5 m high. A profile from the southern bank is shown in Sketch 12.

The interpretation of this profile must proceed from the point of view of the dualism inherent in it. The gravel and conglomerates of the basal strata (e-h) represent the first indication of the great depositions with which we shall become acquainted later. In the upper strata (a-d) the materials transported here by wind and water are mixed together, cemented (or hardened as in Stratum f) by the salt solutions brought up under capillary attraction. The extremely hard salt horizon, a typical junction, contributes to the salt solutions. Horizons such as this one which we found 20 to 30 cm beneath the surface have been noted in other areas. We encountered them with the gypsum crystals east of Khusp (Route II).

After a while we meet a caravan, the last one of the year, they tell us. They had taken wheat to Shah-Dat and are returning without a load. They intend to continue without a stopover to the Khushk-Rud where they cached cut straw on the way out. The camel

drivers in Khanikoff's time used the same method, leaving fodder for the return trip at this same spot. The thirsty camels are anxious to reach the fountain at Ambar, but the drivers will have nothing to do with our suggestion that they seek water at the Bakhtu, for they say that the desert on that side of the path is full of evil spirits.

Three kilometers beyond the Khushk-Rud the Lut is still smooth, covered with whitish brown gravel and fragments of quartz up to egg-size on top of loam or sand. Salt efflorescences begin to appear again, but only on the path itself. We cross another dry river, 30 m broad, completely barren of vegetation, with sand and a few strips of gravel in the bed. As long as it follows our path the bed merges to the flats with hardly a break; only rarely does it have a bank up to one m high. After we have moved upslope for a while in the direction of a hill, salt efflorescences begin to appear beyond the path; the terrain is slightly rolling here, probably indicative of the presence of buried hills, although these do not break through the surface as they have on other routes. The ground around a small, half-buried hill of red porphyry (Rock Sample LXXVI) is so soft that the camel tracks are deeply imprinted; the path through the salt-white sand kavir is set off with stone markers. An excavation here reveals the familiar hard salt layer under 15 to 20 cm of salty sand. Salt also appears in flecks in the gruss which covers the kavir in places. Numerous camel skeletons along the path bear witness to the extreme harshness of this part of the route.

In order to reach the mountain of Gaud-i-Nimeh, which we have been using as a landmark for a long time now, we make a detour

of one km to the right of the path. The shallow stream beds which course down the small alluvial cone are also soft. Even their pebbles are encrusted with salt (the first time we had observed this phenomenon), indicating that there has been no rain here for a long time. The "interstream plateaus," if we may refer to the interstream areas on the alluvial cone by this name, offer the firmest support. In the vicinity of the mountain we find pebbles up to the size of one's hand in the streams. We break a specimen of an eruptive of porphyritic texture (Rock Sample LXXVII) from the encrusted, intensively weathered rock of the western peak, which is about 50 m high, and from the eastern peak a specimen of amygdaloidal rock with schlieren (Rock Sample LXVIII); the weathered crusts of both are a deep black. The "Kanzel" formations of the ridges of the eastern peak exhibit jointing of 140° and perpendicular thereto. Here too we find stone rings like the ones mentioned above. There are no bones, but we could not expect to find such if we are really dealing here with ancient "Towers of Silence." Our original assumption that these might be robber caches now appears less likely in view of the considerable distance from the path.

Looking around we see a few buried hills 25 to 30 km away to the northwest. South of the Kuh-i-Murghab are 2 others which with their disproportionately steep south slopes have the appearance of upturned tables. A tableland rises from the gently downsloping plain and extends over 20 km into the distance (compass 115-145°). Due west, only one km away, is an escarpment with the steep slope facing south. The stretch between the Kellehper Hills and the Gaud-i-Nimeh is almost perfectly flat, depressed only by the 2 dry river beds and slightly dissected. This difficult loam

kavir stretch is called by the camel drivers Gaud-i-Nimeh ("The Depression at the Half-Way Point," i.e., the mid-point between watering places on the route from the Karimabad and Shah-Dat). The sedimentary rocks which appeared at the Khushk-Rud apparently extend only a short distance on either side of the bed. The whitish-brown gravel which covers the surface south of the Khushk-Rud also appears in the vicinity of the Kellehper Hills and to the north of there. The bedrock is probably made up of the same rock (quartzite?). The rolling terrain that we encounter next, the extremely soft ground, and the salt efflorescences, all indicate that the geological structure has changed again. The uneveness of the surface undoubtedly indicates unequal wind erosion resulting from resistance differentiation. The reappearance here of salt efflorescences -- the first to appear in significant quantity for over 100 km -- indicates that special geological conditions permit an issue of water here, a phenomenon possible only in isolated spots and under exceptional circumstances. But our excavation here provided no clue to the circumstances; the observations made at the Gaud-i-Nimeh only confirmed the assumption of an extreme aridity. The dry stream beds, which we had always found elsewhere in the Lut to be firm enough for use as "highways," are soft here. In stream beds where the water sinks in, the effects of chemical weathering are reduced; since the streams in the Gaud-i-Nimeh "break" this rule, we assume that water has not flowed here for years. This assumption is substantiated by the salt-encrusted pebbles and other debris in the stream beds. But observations here also tend to confirm our working theory that the interstream areas offer the best support for the reason that chemical weathering is not so effective there as it is in the lower areas where

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salt solutions rise toward the surface under capillary attraction. Beyond this inselberg the character of the desert changes again. We come now to a series of small undrained basins which, because of their shallowness, might more properly be called pans. Unlike the basins we have crossed before, these all have firm centers and soft slopes and rims. All 4 are ellipsoidal with north-south axes. Moving along the extremely rough path across salt kavir, we reach the center of the first one after 3 km; that of the second 2 km further, that of the third 3.5 km further, and that of the fourth one km further. They are sunk only 4-6 m deep. In accordance with the general slope of the terrain each is lower in elevation than the preceding one. In the third one the kavir characteristics disappear.

The apparent contradiction in the above is explicable thus: the moisture of the kavir evaporates and the hard loam then forms a firm surface.

Sixteen kilometers beyond the Gaud-i-Nimeh, i.e., 2 km beyond the center of the fourth basin, is a distinct scarp leading down into a fifth basin. This scarp is the first of many such we shall encounter further on. The basin, unlike the ones we have just passed through, is drained by a river bed, 50 m broad. This is Tabasan, a rest place for camels; it is probably identical with Khanikoff's "Telli Kalendar" (Terrace of the Dervish) (93).

The outstanding characteristics of the 20-km stretch between Gaud-i-Nimeh and Tabasan are the 4 undrained basins described above. The surface is made up of salt and loam kavir, but also of gruss and a gravel with fragments usually 2 cm in diameter, on occasion, egg-size.

A shallow excavation revealed sand which became looser further down as the cementing effect of the salt decreased. Kavir characteristics are more pronounced in the first and second basins; the caravan path through the dried loam is typically rough. In the third and fourth basins the cloddy kavir disappears, replaced by sand kavir and a gravel mantle. The scarp just a short distance beyond the fourth basin is particularly characteristic of the area; it descends to the Basin of Tabasan and the river of the same name.

Apparently the gravels and conglomerates which we were able to trace beyond Tabasan were represented along the stretch beginning at the Gaud-i-Nimeh and, as a matter of fact, in constantly increasing thickness. In the first 2 basins the salt kavir still forms on the eruptives, but in the succeeding basins a different sort of surface mantle is predominant. The denudational scarp just before Tabasan is the forerunner of numerous others which we shall encounter further south. Thus we have now entered the area of the sedimentary deposits of the Lut after first encountering them in an arm of the Khushk-Rud valley.

From here to the polygon kavir in the heart of the Lut we encountered the following scarps.

Scarp	Height (m)	Distance From Previous One (km)
1 (Tabasan)	3.0	--
2	5.0 (steep, unbroken)	5.0
3	2.0	0.7
4	1.0	0.5
5	0.5	2.5
6	2.0 (obliterated brink)	0.5

Scarp	Height (m)	Distance From Previous One (km)
7	1.0	2.5
8	10.0 (with a ledge)	0.5
9	5.0	3.5

The scarps have less gruss but more salt than the surrounding area. At the edge of the seventh are beds of sand and gravel mixed with a fine dust. The terrain between scarps slopes steadily downhill, especially so beyond the last one, which together with a pediment leads over into a polygon kavir. The ground is covered with gravel, gruss, or sand; not far from the second scarp there is a dense mantle of gravel. Where the scarp plays out the egg-size gravel usually gives way to gruss. The more or less firm ground usually turns soft near the edge of the scarp. There are numerous depressions in the areas between the scarps, an indication of the intensity of the deflation.

At the base of the scarps there is more dust than gruss; the steep faces are often of sand cemented by salt. In a small stream bed between the sixth and seventh scarps we broke a specimen of bedrock in the form of sandstone with salt crystals (Rock Sample LXXIX).

The surface material along this last section of the route did not look like compacted, jointed Hammada-type rock, but was strewn over the surface, even where it consisted of gravel. Sand often appeared on the surface, in connection, no doubt, with the structure of the scarps; the layers of the dust were protected by a crust of dust and salt. In walking, we broke through this thin layer very readily; nevertheless it has apparently offered considerable

resistance to the processes of deflation. Ripple marks appeared chiefly in the sandy stream beds. In the south and west we saw numerous small dunes as well as the mushroom rocks of the disintegrated tableland which we shall become acquainted with later.

We encountered salt efflorescences only rarely. The path, paved with gravel trodden into the surface, was firm. The terrain, unlike that of the previous section of the route, exhibited numerour dessication cracks. On 26 March we traveled down the Tabasan river valley. Since it is similar to all the streams which cut through these scarps and empty into the heart of the desert, we shall present our observations on it at this point in our report. These observations are presented in tabular and graphic form, following a method we have used elsewhere (141) in graphic form analysis /see Sketch 13 appended/.

The valley itself, of course, could only have its origins in the desert fringe areas; it is probably a branch of the Khushk-Rud. The cases of subdivision are particularly interesting in connection with the problem of erosion. The river breaks up twice, namely at Points 15 and 17 /see Sketch 13 and the accompanying chart/, but not at the broad places at Points 10 and 11 b; indeed, the first instance (Point 15) occurs where there is a relatively steep gradient. Before reaching Point 15 the stream passes through the stretches of active downcutting between Points 12 and 14 b. The steps in the long profile indicate that downcutting is still in progress; apparently the stream becomes so laden with debris here that it is no longer capable of downcutting: with little depth and almost level gradient, it overflows its banks and breaks up. At point 14 b the main erosion channel divides into several

smaller ones and the stream shows a tendency to subdivide; but further progression of the tendency is prevented by the steep bluffs. Further downstream these bluffs extend outward on either side as scarps. At Point 16 a, where the main channel encounters a small scarp, it begins to meander and resumes its downcutting. This process of subdivision following intensive downcutting is repeated, this time along a less steep gradient.

The examples of subdivision here bear out my ideas toward a theory of erosion which I have dealt with elsewhere (145, among others). Where erosion is in process the stream becomes so laden that the speed of its flow is reduced to the point where it begins to deposit the transported material; on alluvial cones or on gravel, which are readily eroded, the bed is raised through excessive deposition to the point where the river overflows the banks and breaks up into distributaries. The scarp at the fourteenth kilometer is particularly interesting. To be sure, there are no falls in the river bed itself reflecting the change from horizontal beds of sand, gravel, and clay, but the river's long profile as a whole is convex when the downcutting can work more effectively in an upstream area than a downstream area. This is readily understood in the area of intensive downcutting between kilometers 8 and 9. But there is no such parallelism in the stretch between kilometers 14 and 15.5: the depth is actually less here in spite of the steeper gradient! The reasons for this break in the profile are probably morphological rather than geological, for the genesis, not the bedrock, is responsible for this scarp formation: the process of downcutting was rejuvenated by a sudden lowering of base level. We may be dealing here with the effects of an elevated beach.

This past section of the route provides us with insights into the nature of the great depositions which we refer to as the "older" sediments, as distinct from the "younger" which we shall discuss later. Between the denudational scarp just beyond the fourth basin and the beginning of the salt slab kavir the thickness of these deposits amounts to 200 m. But they undoubtedly continue beneath the polygon kavir, so that they are actually much thicker.

In our route across the older sediments we had to climb down 10 scarps ranging in height from 0.5 to 10 m. The steep faces were made up of coarse, half-compacted conglomerates, of salt-cemented sand, or of clay. Along here we observed the older sediments in horizontal beds only. From the Gaud-i-Nimeh we could see west of our route 2 tilted tablelands (compass 100-120°) dipping to the north, but we were not able to ascertain whether or not they were constituted of the older sediments. Adjacent thereto, west of our route and south of the Kuh-i-Murgh, is a horizontal tableland; from the mountain of the Gaud-i-Nimeh it could be sighted at 115-145°. We were able later to take sightings on it repeatedly and finally identified it as a great gravel deposition extending north-south along the Shur-Rud valley depression on the western edge of the Lut. These deposits are not directly connected with those we encountered on the way down; the topography between the 2 is characterized by typical disintegrated remains of such gravel tablelands, i.e., by the yardangs, pyramids, pillars, etc, which are called Shahr-i-Lut (Lut City) by the camel drivers. They were described and depicted repeatedly by Gabriel. A connection apparently existed at one time, but it was reduced to the forms described above by the processes of denudation. (For a

picture of these forms, see 137, page 133.) Khanikoff calls these tablelands "Ghendoum Birian" (Roasted Wheat).

It is understandable within the framework of the rules which govern such landscapes that more salt should occur in the scarps, for salt cements and thereby makes the rock more resistant. Hammada-type rocks, the distinctive sign of primary deposits, do not appear in the gravel. But it is interesting to note that the coarser constituents appear on the interstream areas and the finer ones in the dry stream beds. It would be a mistake to attribute this phenomenon to the effects of running water, however: it is probably the result of wind activity.

These great deposits provide a few insights into the genesis. Looking southward from the gravel scarps, we have a broad view over the great basin of Shah-Dat (Khabis), which is covered with the gleaming slabs of a polygon salt kavir. This basin extends out of sight to the south, where it was crossed by Gabriel on his last important expedition. It ends in the east after a long gradual upslope at the East Iranian Mountains and the great dunes chain which lies in front of these mountains. Since it is also bounded by mountains in the south, its basin character is complete: only the 200-m high sedimentary tableland in the north, from which we look out over this panorama, does not constitute a definite closure, but rather a scarp.

C. The Heart of the Lut

After descending from the scarp landscape described above we reach the actual core of the Lut. The heart of this broad basin extends out of sight; it is almost perfectly level, perhaps with

a slight slope to the south. I assume that this is the salt marsh marked on the maps as Namakzar, but I must confess that I never heard the camel drivers use this name. Out of this gigantic honeycomb of polygon kavir rise 3 elongated ridges 10 to 20 m in height, made up of conglomerates and sandstone or sand. They run diagonally to the SSE; with their towers, pinnacles, and cliffs they look so much like the ruins of houses that they are described by the camel drivers as Shahr-i-Lut, "Lut Cities" built by Rustam and once inhabited by giants. They are also called Nagoreh-Khane locally. I am not too clear as to why Khanikoff (loco citato) called these denudation remnants "limestone cliffs" (page 415), since they have nothing to do with either limestone or cliffs.

The clods of the dry, light brown loam kavir, which is mostly free of gravel, are thrown up as high as 30 cm and spanned by the latticework of the polygon edges. The clods, forced out of their pattern, often standing upright, create a surface similar to that of a crater field; since this is difficult to drive over we seek out a way toward the abrupt slope of the tableland mentioned above. The surface, with sand ripples running east-west, is smooth, but it soon gives way to another "crater field" which, to be sure, is dry and firm enough, but hardly suitable for driving. Therefore we return to the caravan path. The latter leads for about 500 m over a smooth, firm desert floor with a thin pavement of plum-size gravel; in places the ground is only strewn with fine gravel.

After traversing this stretch of firm ground, which is probably only the last remnant, the "pedestal," of another elongated ridge, we reach the salt polygon kavir; the polygonal slabs are so firm that although they readily sag under the wheels of the car,

they do not break. Of course, wherever there is a gap under the polygons (only rarely filled in with salt crystals) one can count on breaking through. Just a few meters before we reach the first of the elongated ridges, the salt polygon kavir is covered with dunes sand. We camped (Camp 49) for 3 days from 24 to 26 March between the 12-m high walls of the Shahr-i-Lut. The area, which is frequently used as a camel resting place, is strewn with the skeletons of these animals.

In order to gain information about the stretches we still have to drive over, we wander along the path for one km till we reach the 10-m high second ridge; its southwest side is covered to the top with transported sand. We cross an area of salt polygons 500 m broad with upturned and half-upturned slabs and arrive at a depression 200 m broad but in no place more than one m deep; it is veneered by a tenuous, undeformed, brown loamy kavir with polygons marked with smallish knobs. On the rim of the depression the clods have broken out of the pattern and stand up obliquely, but not to an extent great enough to form one of the dreaded "crater fields." After another kilometer we come to 2 smaller depressions of the same type. Just before we reach the third of the elongated ridges we again encounter the upturned polygonal salt slabs standing obliquely. One would think that the polygonal slabs and clods would break up near the ridges, that in the flow movements of the kavir they would be "dammed up," as O. von Niedermayer put it, wherever they encounter a firm prop. On the contrary, next to the first of the elongated ridges and near the adjacent zone of drift sand the polygon kavir lies undisturbed.

In order to survey this "heart" of the desert, we climbed a "tower" 20 m high on a third ridge, which is in the process of disintegration. To the north we take a sighting (13°) on the Kuh-i-Murghab, the silhouette of which has accompanied us all the way to this point; also north of us is the precipitous face of the tableland Ghendoum-Birian which is 4 km broad; it constitutes the northern rim of the basin. It descends to the kavir by a series of small scarps with numerous little towers, jags, mushroom rocks, and other bizarre forms which we shall encounter later. In opposition to the general slope of the terrain, a horizontal tableland extends northward from the steep face of the Ghendoum-Birian. We had already noted this formation from the Gaud-i-Nimeh; from here it is clearly apparent that like its frontal face it is constituted of sandstones and conglomerates. The sedimentary fill of the Lut extends tongue-like to the north, a phenomenon important for the chronogenesis of the relief. In the west we recognize a bright ribbon as the Kal-i-Shur, the salty compound river on the western edge of the Lut. Gabriel (60) crossed this narrow stream only 6 months later. Beyond the river, among numerous other Lut Cities, is the notorious Gudar-i-Barut (Powder Keg), where the Baluchi used to hide, lying in wait to rush out and attack passing caravans. In the south the kavir is bounded by a confusion of small Lut Cities with towers, mushroom rocks, and walls which give the impression of a great tent city stretching away out of sight. It would be difficult indeed to find a path through this labyrinth of palisades, despite the fact that none of the forms are very high. The "tent city" is apparently united by a level 10-15 m high. The whole apparently constitutes the remnant of a young sedimentary tableland of the same character as

the 3 elongated ridges. The kavir stretches away to the east, broken in places by the ridges; a short distance from here, however, they begin to show signs of disintegration. Far away on the eastern edge the basin is bounded by still another tableland. The caravan path continues for a few kilometers SSW and then joins the path from the east, i.e., from Deh-Salm.

During our stay in Camp 49 we investigated the kavir and polygon formations. Gabriel (60), out of his rich experiences, has done an excellent job of classifying the types of kavir soils. He follows the natives in the vicinity of the Great Kavir in distinguishing between the following main types.

1. Zardeh (yellow): yellowish brown, hummocky loam soil uniformly interspersed with salt. Occurrence: marginal areas of the Great Kavir.

2. Carbeh (fatty, greasy): darker, moister places interspersed in other types of soil. Occurrence: irregular; frequently in strips and bands.

3. Namak siyah (black salt): alternate beds of clayey mud and pure salt; hard, friable, and firm; often compacted, with hummocks and knobs and veneered by a rind of effloresced salt which keeps the top bed moist. Occurrence: the lower areas of the Great Kavir.

4. Kaseh (shell): a transitional formation of burst domes 3 m high; a confusion of hollows and joints over a corroded and cracked surface. Occurrence: lower areas of the Great Kavir.

5. Namak sefid (white salt): slabs, usually hexagonal, often several meters across, uniformly veneered by a salt crust. The edges of the slabs are upturned. Occurrence: the lowest areas of the Great Kavir.

Gabriel crossed the kavir of the Lut core for a distance of 20 km, west to east, along a section of the caravan route somewhat south of our present position. He describes it as a loamy ground with ridges and valleys: "The surface is not cracked. There are no clods broken loose from the pattern" (60, page 219).

North of his route we found conditions somewhat different. I cannot say with certainty whether the kavir to the south has a basically different appearance, or whether this difference is to be attributed to the difference in time: no doubt the ground was moister at the time of my visit (March 1933) than it was during Gabriel's visit (October 1933).

According to our observations the polygons, or rhomboids, characterize the heart of the Lut: we did not observe this phenomenon in any of the other kavir areas we encountered in the Lut. Judging by the descriptions by Hedin (77), Niedermayer (106), and Gabriel (58), however, these formations in the Lut are by no means so grandiose as those in the Great Kavir. The network of rhomboids shows through the surface, or it rings the polygonal salt slabs with small, upturned clods. In only a few following places does this network not appear.

1. The few "firm" places, isolated islands in the sea of kavir, represent the remains of residual hills of the "young"

sediments which have been worn down almost level; they are strewn with gravel or gruss or in places even veneered by a thin pavement. They usually occur along lines running in the same direction as the elongated ridges and beyond the point where the latter play out; therefore, they actually are the leveled remains of these disintegrated ridges. As such they have not yet been taken over by kavir and therefore do not exhibit the rhomboidal forms, for the natural polygons do not occur outside the kavir zones.

2. The polygons do not occur, of course, where the ripple-mark sand occurs. The latter usually appears in the lee of the elongated ridges, but also turns up here and there in large and small fields on top of the kavir. It is hardly conceivable that such fine sand, often mixed with dust, could remain on these flat areas during the violent storms; the fields must be formed as the storm dies down and therefore they could not be older than the last strong wind. This assumption is further supported by the fact that the ripples are veneered only here and there with a thin crust of salt; apparently there is not sufficient time between storms for such crusts to form, except in isolated places.

3. As I have already indicated, the kavir of the southern Lut is by no means perfectly flat, entirely apart from the miniature relief of the polygons and clods; there are faint depressions, shallow pans, and, especially in the fringe areas, small washes, the last branches of the subdivided streams from the higher scarp zones. Such small furrows or troughs also extend outward from the elongated ridges. The floors of the pans are covered here and there with gravel or gruss; the sand has usually been blown away but occurs sometimes in places where it is protected by coarser

materials. The narrow, shallow beds of the washes sometimes contain fairly coarse pebbles from the "older" or "younger" sediments but usually contain gruss. There are no polygon formations in either the pans or the washes. An excavation near one of these revealed a 5-cm thick layer of gruss over 20 cm of fine sand; beneath the sand was loam. A brown, loamy kavir soil in cunieform pattern begins at the banks. The rhomboid pattern usually does not appear until the loam is at least 7-10 cm thick, but begins immediately where the slopes are covered with a layer of salt. The gruss and gravel in the pans are strewn over a layer of amorphous sand rather than polygons; but in those parts of the pans where there is no gravel or gruss the polygon pattern is well developed.

4. As we pointed out at the beginning of this chapter, the polygons veneer the loam clod kavir without regard to its surface configuration. Later on in the salt polygon kavir the slabs are raised in their polygonal form out of the pattern. In the loam kavir, on the other hand, the clods usually break outside the network, and the rhomboid pattern instead of following the line of the clod edges dissects them. The hard knobby formations (which are probably remnants of clods which have been forced up or else clods which have been raised up but have not yet burst) do not exhibit polygon forms where they are strewn with considerable amounts of sand and gravel; this is usually the case in the vicinity of the scarp zones.

With the exception of these 4 cases, the network of the polygons extends over all the kavir areas which we visited on the heart of the desert. Of course the phenomenon is more pronounced in some places than in others.

We came to distinguish between the following types.

I. Polygon Kavir Without Salt Slabs

(a) Clay and Loam Polygon Kavir. This type, which is not common, occurs in the form of flat stretches of loam or clay kavir veneered by a very thin salt crust, or, more properly, a salt rind. In its bareness it contrasts sharply with the polygonal salt slab kavir, near which it usually occurs. But it also occurs elsewhere: only in the depths of the pans does it never occur. The polygon pattern is usually very faint, being merely suggested by narrow bands. An excavation here revealed a salt rind 2 mm thick, a layer of salt and loam or salt and clay 10 to 20 cm thick, and then fine sand.

(b) Light Brown Clod Polygon Kavir. This type of kavir consists of light brown, loose loam soil interspersed with salt crystals overlying a gray, more sandy loam, also interspersed with salt crystals; the latter overlies the hard, salt sandstone familiar to us from earlier excavations. At the surface are numerous knobs, bulges, "horns," and jags surrounding small holes or trenches. Frequently the clods are pressed out of the pattern like blocks of ice in an ice jam and burst, forming the dreaded "crater fields." Sand or gruss is strewn over the kavir in places; at the time of our visit it was dry and hard. Usually though not always, this type appears in the fringe areas. In places the salt slab polygons (to be described below) extend to the margin of the scarps or their pediments and the light brown clod kavir begins further on or not at all. In any case it appears to be restricted to the fringe area. Of the types in Gabriel's system, it is most nearly comparable to the zardeh (type 1), which, according to Gabriel,

also occurs in the fringe areas. Hedin too usually found this type around the edges of the Great Kavir. Where the clods have been thrown up, however, this type resembles the kaseh (type 4) most closely, although the shattered blocks here in the Lut are thrust up at most 30 cm, and never form "domes a meter high" as they do in the Great Kavir. In Deh-Salm this type is also called kasch kavir.

All of the kavir described in I is covered with polygon lines like grooves traced with a stick; they run across "mountain and valley" without regard for the configuration of raised blocks and small trenches. The blocks set off by these lines are usually 5-sided or 6-sided, sometimes more; they measure from 50 to 20 cm in diameter. The grooves which form the sides of the polygons consist of fine sand which extends through the upper loam bed down into the lower one.

II. Salt Slab Polygons

The greater part of that area visible to us from this part of the southern Lut is covered with salt slab polygons; the resulting fantastic appearance is best described as a gigantic honeycomb. We distinguished between the following types.

(a) Undisturbed polygonal salt slabs lying flat on the surface with sand constituting the lines between. The slabs have 5, 6, or more sides; they have proportions such as 75 x 100 cm, 90 x 150 cm, or 50 x 80 cm, but never attain to the sizes observed in the Great Kavir by Hedin and Gabriel (as much as 8 m in diameter). Each polygon is a hard block of salt from 5 to 10 cm thick; most of them can be lifted in one piece. A thin crust of sand and dust

is baked on to the hygroscopic salt, giving the surface of the slab the appearance of a huge poppyseed roll. The polygon is surrounded by a roll-shaped rim of sand, here and there by a double roll with a groove in the middle which looks like a mark one might make in sand with the finger. The excavations we made in this type revealed the following beds (see Sketch 14-I).

1. One centimeter thick: a cap of dust, drift sand, and gruss often full of holes.

2. 5-10 cm thick: hard, porous salt slab, dirtied on the under side by loam heavily interspersed with salt crystals (Rock Sample LXXXII).

3. Up to one centimeter thick: loose sand with salt.

4. 4-5 cm thick: the same sand with salt but partially cemented.

5. About 0.5 cm: an horizon of salt crystals.

6. 8-12 cm thick: venetian-red, fine, very finely laminated clay (Rock Sample LXXXIIIa); slightly salty and somewhat moist; clearly distinct from No 7.

7. About 5 cm thick: gray, laminated clay, slightly salty, somewhat moist.

8. 5-10 cm thick: fine loose, somewhat moist sand; isolated grains as big as 2 mm; isolated grains of salt.

9. About 0.5 cm: salt horizon.

10. 20-25 cm: reddish clay.

11. Brown loam.

This type usually occurs in level terrain, never in the dissected kavir. Gabriel describes a variation of the namak sefid which results when clayey-muddy subsurface material wells up between the blocks and surrounds them with "walls." In our case, as we have already pointed out, the polygons are surrounded by sand in the form of a double groove which apparently forms as the result of the sands being squeezed out under pressure from 2 blocks.

(b) Polygonal salt slabs with raised edges. These polygonal slabs differ only slightly in form and size from those described under "a) above. They are separated from each other by raised edges in the form of little "walls" as much as 10 cm high. Frequently the slabs have been completely raised out of the pattern or tilted on their sides, so that one frequently breaks through into the resultant empty space. Gabriel described the same type in the Khurasan Kavir as tabakeh kavir. To be sure, the forms we encountered in the heart of the Lut were considerably smaller than the ones he describes, both in the diameter of the slabs and in the height of the rims (as much as 20 cm in Gabriel's case); on the other hand the slabs in the Lut are considerably thicker than those noted by Gabriel (one to 2 cm in his case). The results of our excavations in this type are as follows (see Sketch 14 II).

1. Up to one centimeter thick: a cover of dust, loose sand, and gruss, often full of holes.

2. 5-10 cm thick: a hard and porous salt slab (as in No 2 above), dirtied on the under side by loam interspersed with salt crystals.

3. 8 cm thick: slightly cemented sand with a little salt (similar to No 4 above).

4. 20 cm thick: hard salt sandstone with large salt crystals vertical.

5. About 15 cm thick: light brown loam with sands.

6. About 0.3 cm thick: a salt horizon similar to No 9 above.

7. 10 cm thick: gray clay (similar to No 7 in the table above) with interbedded small salt horizons occurring irregularly. Infrequent, small spots of reddish brown clay which merges to No 8 below.

8. Brown loam similar to No 11 above.

Type "b" is extremely widespread. It occurs on the other side of the second and third elongated ridges and over a large area in the vicinity of the first of these ridges, but, as we have already mentioned, we were not able to establish any pattern of occurrence. Unlike type "a," type "b" is not restricted to flat terrain.

(c) Broken salt slabs. This is a variation of the type described above in which both the polygonal slab and the edges are raised up. The slab is broken in or near the center, leaving the 2 pieces overlapping or pushed up to form a small pyramid. Apparently the pressure which had already forced the edges up was so great that the block itself broke. Significantly this type usually occurs in a gently sloping terrain, but it also occurs isolated in flat areas. The substructure is similar to that described in b.

On the basis of these observations we may draw a few conclusions about the rhomboid forms of the loam kavir, bearing in mind that our conclusions are in need of additional confirmation.

First, it is apparent, not only that the rhomboid formation requires loam soil, but that it requires a definite thickness of loam (at least 7 to 10 cm here). Second, a large quantity of sand or gravel strewn on the surface will hinder the formation. Apparently the process begins when polygonal dessication cracks develop in the clay or loam; these cracks are filled in by salty, moist loam forced upward as a result of internal tensions. The upturned blocks of the "crater fields" bear witness to the existence of these tensions -- and in places to their amazing force. Wetzel (163) also mentions them. They may result from the salt crystallization. It is doubtful that they are the result of flow movements. The observations we made repeatedly in the northern and middle Lut demonstrate that such bulges and eruptions can develop without accompanying polygon formation. It is significant that we first observed the rhomboids in the southern Lut. I attribute this to the fact that only the Namakzar has the necessary moist and labile material to fill out the polygonal fissures. We shall refer to the excavations again in Route V.

The profiles of the individual elongated ridges were examined. The following represents the profile taken at the third elongated ridge.

i. 20 cm: brown, sandy-loamy salt kavir soil with salt crystals and rounded or angular quartz up to egg-size.

h. 100 cm: light yellow, very hard, viscous, fine-grained sandstone (LXXX).

g. 200 cm: light brown, fine-grained sandstone of medium hardness.

f. 300 cm: finely laminated grayish brown clay.

e. 200-1,000 cm: fine sands, frequently in deltaic shape but usually bedded horizontally; in the process of cementation.

d. 20 cm: porous, medium-grained sandstone of medium hardness; stands forth clearly in the form of roll-shaped bulges.

c. Approximately 500 cm: clays and sands alternately bedded.

b. 20 cm: bed of hard sandstone.

a. Approximately 150 cm: clays and sands alternately bedded as in "c" above.

The following is the profile at the first elongated ridge near our camp.

i. 20-30 cm: brown, sandy-loamy salt kavir soil with salt crystals and rounded or angular quartz as in "i" above.

h. 30 cm: light yellow, relatively fine-grained sandstone similar to that in "h" above but not quite so hard.

g. 200 cm: clays and sands alternately bedded.

f. 0.2 cm: gypsum band.

e. 100 cm: light, finely laminated clays.

d. 0.3-0.5 cm: gypsum band.

c. 200 cm: clays and sands alternately bedded; sands, frequently in deltaic shapes.

b. 100 cm: light, very fine-textured clays.

a. 400 cm: light, very fine-grained sands, half-cemented, often in delta shapes.

These profiles are similar in a limited sense only, although they are only 6.5 km apart. We must discuss them in connection with Huntington's observations (83) and other discoveries.

Because of their recent character and because they are sealed off by the layer of kavir over the hard, fine-grained sandstone they have in common, it is definitely clear that these deposits are not denudation remnants of those sedimentary deposits which constitute the scarps we crossed on the way down: they must be much younger. We therefore distinguish between the "younger" and the "older" sedimentary deposits in the heart of the Lut.

We undertook an analysis of these profiles (in connection with observations made by other authors in nearby areas) in the special study "Pleistocene Deposits in the Heart of the Lut Desert" (Festschrift der Geogr. Gesellschaft /Anniversary Publication of the Geographic Society/, Vienna, 1956). As we indicated in this article, the older pluvial period in which the distinctive "older" sedimentary deposits were laid down, began after the most recent epeirogenic movements, during which the basin subsided from Shah-Dat to the middle Lut. The lake which formed in the heart of the southern Lut was filled in from the edges. The aqueous loess which forms the grandiose "boulevards" discovered by Gabriel (62) was deposited toward the end of this pluvial period.

This pluvial period was followed by an arid period apparently drier even than the present-day one. It was characterized by

intensive deflation and by violent storms by which the "older" sediments were eroded away, in places even under the present-day kavir level. The material was transported chiefly by the west and northwest winds and deposited for the most part on the southeast edge of the desert, where it has been piled up in the great dunes which are among the largest in the world.

This arid period was followed in turn by the more recent pluvial period in which the "younger" sediments were deposited. Another lake probably formed in the heart of the Lut at this time, but it was not as large as that of the first pluvial period, nor did it survive as long. Indeed the "younger" sedimentary deposits are only about 1/10 as thick as the "older." Moreover the more recent pluvial period was characterized toward the end by a phase of fluctuations, including a stage of kavir formation just prior to the beginning of the more recent period of deflation. This latter, a period of intensive denudation, was followed by the present climate (which we shall discuss in detail in Route V).

One is tempted to relate these 2 basic climatic changes to the last 2 glacial stages, i.e., to equate the older pluvial period with the Riss and the more recent with the Wuerm. To be sure, this can be justified only on the basis of conclusions arrived at by analogy.

We made the following observations on the weather. On 24 March at 1900 hours with no wind and only a few scattered cirri in the sky we recorded 24° C, only 3° less than it had been at 1600 hours, the time of our arrival at the heart of the desert. The low that night was 5° without dew formation; at 0630 hours on 25 March with no wind and a clear sky the temperature stood at 7°. Thereafter

there were light gusts from the south but the sky remained clear; by 1300 hours the temperature had climbed to 28°. We measured the atmospheric moisture at 19%; our instrument, however, was no longer entirely reliable. By 1500 hours the gusts from the south had increased considerably in force and the temperature had climbed to 30°; by 1900 hours it had dropped to 25°. The night was extremely warm and close with gusts from the south. On 26 March at 1000 hours there was a gentle wind from the south and the temperature stood at 22°. The wind soon increased, bringing higher temperatures and on occasion a clearly noticeable mugginess. About 50 km west of Camp 49, but still in the heart of the desert, the temperatures were 31° at 1300 hours and 33° at 1500 hours. The west and east wind created spouts now and then. In Camp 50, 400 m higher, the temperature was 24° at 2100 hours with a south wind which later turned to a violent sandstorm that lasted all night. The first clouds appeared at 1900 hours, later assuming the character of nimbus clouds. The aneroid readings ranged throughout the day from one to 1.5°. I have discussed these weather statistics in a special treatise.

All further plans in the heart of the Lut were ruined when the radiator was damaged. Moreover our large tank had become leaky and most of the water drained away, so that we had to find a watering place as quickly as possible. We decided to make for the oasis of Deh-Salm. In order to avoid the "crater field" of the kavir we drove back the way we had come as far as Tabasan and then proceeded down this valley. (We described our personal experiences in this race with thirst in Volume I; it also includes a few pictures.)

We now stand once again in the kavir, only 11 km from Camp 49, so that we have gained but little by our acute-angled detour. The polygonal salt slabs with small clods are strewn with gravel at first. We stay as close as possible to the slope, moving over a thin layer of coarse gravel and very soft sand, in order to avoid the polygon kavir. The familiar scarp zone to our left sinks gradually to the kavir; to the right a broad, flat kavir extends southward to the "tent camp" of a Lut city. To the east a few terraces detach themselves from the scarp zone and extend along a cresentic line into the kavir, forming the first significant relief features we encounter in this plain.

Another 4 km and we reach the first rise, i.e., the first terrace, which runs along at a height of barely 1.5 m without working any change in the nature of the kavir. We turn left toward a second, higher terrace. The ripple marks, witnesses to the force of the wind here, are no longer formed of sand but of pea-size gravel; they are about 50 cm high and run ENE-WSW. The sand has been blown away except for that on the leeward side of the terrace, there where the steep side faces toward the northwest. In the kavir to the right is a mushroom rock one meter high, the last remnant of an erosional hill; shattered by the wind and corroded by salt, it has assumed an almost ideally streamlined form. The kavir here, which is upturned here and there in blocks as big as 30 cm, is moist in some of the deeper spots, but this does not involve any change in form; the presence of the moisture is indicated only by the darker coloration. Interestingly the polygons here at the edge are only half formed. The transition is so sudden that there are no unusual phenomena. Apparently the edge of the kavir as such does not act as a "buttress" in the process of polygon

formation, for if this were so, the perfectly formed polygons would extend right to the edge.

We rest for a short while under a remnant of the disintegrating terrace, a mushroom rock formed by a stratum of soft sandstone between 2 harder ones. These sandstones are of an entirely different type. They are more firmly cemented, leached out, and older. From this height we can see the path to Deh-Salm leading eastward across the flat kavir; it is marked off with blocks of salt as guide posts. We head toward it, driving between the foot of the disintegrating terrace and the edge of the polygon kavir, which is now loamy and strewn with gravel and gruss. The terrace ends in a group of Lut cities; the towers, smallish mushroom rocks, and elongated ridges, which exhibit a uniform upper level, show clearly the effects of abrasion. But these are different from the Lut cities of the elongated ridges described above: the rock is harder, the overlying kavir stratum is missing, and their connection to the great "sedimentary tablelands" in the north is obvious. The path to Deh-Salm, which we reach at this point, no longer leads across kavir soil but over firm ground strewn with sand, gruss, and plum-size debris of quartz. The polygon kavir of the heart of the Lut is now behind us; we have come once more to the sedimentary deposits. These can also be recognized to the south, disintegrated into Lut cities. This is a clear example of how the degradational process proceeds: the sedimentary tableland is not worn down and leveled as a unit; rather it is broken up into Lut cities and elongated ridges, the individual parts of which subsequently fall prey to the destructive processes. A broad ridge had developed in front of the lowest level. It is possible that we are dealing here with an elevated beach, since for long stretches the strata did

not exhibit the heterogeneous composition. Since we were already suffering for lack of water we were not able to investigate thoroughly.

We were not able to determine on the basis of the aneroid (the daily range of which was greater than the amplitude of the elevation differences) whether the large kavir area slopes from east to west. The sextant also proved unreliable in the vibrating air. It is certain that the polygon kavir begins to slope gently downward right at its edge; the gullies which fan out where the streams subdivide all indicate definitely a slope from north to south. There also appears to be a very gentle slope from east to west. We have the impression that the edge of the kavir here is at the same level as the tops of the elongated ridges. It is well known that the Great Kavir is also basined.

From the edge of the kavir basin to the edge of the sedimentary tableland, a distance of 60 km, the caravan path leads uphill and down, rising a total of 250 m in elevation. We are accompanied all the way by the face of this tableland or by the "step city" /Staffelstaedte/ which extend outward from it. Thus we climb over rolling terrain once again to the tableland, which here in the east is 50 m higher than at Tabasan. The following information is presented according to distance and relative height, beginning at the edge of the kavir.

At 2.5 km, 6 m higher, after crossing a scarp covered with transported sand, we come upon a confusion of hills and "Kanzeln" of the disintegrating terrace (which consists here of loam and extremely crumbly sandstone). The camel drivers call these hills Gusheh-Meighani. The ground is very soft and dotted with isolated

salt efflorescences, the only ones we observed along this stretch. We should surmise that the water level of the kavir area we have just traversed extends to this area.

At 4.5 km, 40 m higher, remnants of disintegrated sedimentary scarps appear in the form of elongated ridges, mushroom rocks, "Kanzeln," and other residual rocks. Sand is deposited in typical delta form on the leeward side of these formations. The individual rocks are joined into numerous chains with various levels represented by the harder sandstone beds. The low blocks, about 5 m high, are rounded on top, since the harder sandstone bed is in the middle here.

At 6.5 km, 53 m higher, on the second sedimentary scarp we wander about looking for a passage through a confusion of mushroom rocks. The same disintegration forms can be traced far to the north; in the south the bedding plane breaks up into Lut cities and similar rock labyrinths.

At 8 km, 85 m higher, on the broad ridge of the highest scarp, there are similar "Kanzeln" and rock forms. The stream beds running south from the higher table on the left contain a fine gray sand in their beds; it was deposited there by the wind, not by water.

At 9 km, 70 m higher, we climb to a broad flat area from which we can see another long ridge 5 km away to the north; remnants of it, 700 m long and 20 m high, can be seen to our right. There are numerous small sand dunes here with slip-face on the southeast.

At 11 km, 55 m higher, after climbing down another scarp, we find ourselves in what appears to be a bed similar to that at the 6.5 km mark. Disintegrated into a maze of sandstone blocks it has the same height of 3 m under the protection of a hard stratum. To the left, toward the table, the maze becomes denser; to the right it gradually plays out. The rolling surface here is strewn with gruss.

At 12.5 km, 43 m higher, after climbing down still another scarp, we come to an area of towers and cones, the highest point along this stretch. Before us is a flat area bounded one km to the left by a sedimentary table with a steep slope in 3-4 stages. A few spurs run out to the right, half destroyed and buried in sand. After we have crossed an extended, echeloned, southeastward-ranging spur of the sedimentary table, we find ourselves at approximately the same elevation as at the 4.5 km mark; we remain at this elevation for the next 2 km. The plain, which slopes gently to the south, is firm and free of salt efflorescences; it is covered with an unbroken layer of gravels, usually pea-size, occasionally as much as egg-size.

At 15.5 km, 60 m higher, we have been moving gradually uphill over a slightly rolling terrain without, however, encountering a notable escarpment. To the left appears the first large elongated, echeloned ridge called Puseh-Gushkal by the camel drivers. It is made up of from 3 to 5 levels; at the foot it is partially covered with sand and gruss. Remnants of "Kanzeln" have been weathered out of the great ledges in forms so fantastic that they resemble buildings in the Babylonian style. Despite the fact that the overall height seldom exceeds 120 m, the ledges have the appearance at

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times of a gigantic amphitheater, at times of modern skyscrapers. As is usual in scarp zones, the brink is made up of hard sandstones while the face itself consists of clays or soft sandstones. The high formation plays out in steps. To the right is a small elongated ridge only 12 m broad which disappears in sand and dunes.

At 21 km, 35 m higher, after crossing 2 low, narrow spurs of the table, we reach a basin lying between the first Staffelstadt (Pushe-Gushkal) and a second one around which we have to detour. The narrow, sandy gullies in the basin run off into a brown clod kavir -- the first kavir soil we have seen since leaving the great polygon kavir. The path leads across a rolling (but no longer escarped) terrain covered with gruss with soft patches of sand. The kavir no longer exhibits the rhomboid formation.

At 25 km, 60 m higher, as we approach the second Staffelstadt the path begins to climb again. Twenty kilometers to the right the formation is continued by a similar one of the same height trending in the same direction. We cross a gully, actually only a strip of sand which becomes a river during the rare rainfalls. In the broad basin to the right (28 km away, 40 m higher) a brown clod kavir appears again, softening the gruss-strewn floor except in the immediate area of the pediment. This second Staffelstadt appears, not as a spur of the tableland, but as a broad, elongated ridge ranging off to the southeast. Here too we find sandstones of various color, hardness, and granularity alternately bedded with clays. We drive uphill and down past buried and disintegrated rock walls, cross a new, smaller ridge and at the thirty-second kilometer mark arrive at the third Staffelstadt.

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At 32 km, 70 m higher, the ground is once more firm, covered with transported gruss or decked with an unbroken deflated surface of plum-size quartz. Fragments of eruptives begin to appear on the surface again. The ridges of the dunes cut across our path (southwest-northeast) running at 320°.

At 34 km, 70 m higher, the third Staffelstadt and its 2 spurs lie far to our left. We climb over a scarp covered with transported sand and on the other side come upon almost cresentic dunes of coarse sand, frequently of gruss. A hill we sight to the east is the first to exhibit a peak like those of the inselbergs instead of the familiar table form, indicating that we shall soon pass out of the sedimentary deposits. To the south however the sedimentary tables stretch away out of sight; apparently the floor of the desert here is made up of the "older" sedimentary deposits.

At 38 km, 80 m higher, the fourth Staffelstadt, which now appears ahead of us, extends beyond the inselberg; therefore, the latter must have been in existence before the deposition of the sediments. The ridges of the semicresentic dunes still run northeast-southwest. The ground is firm, covered with a dense unbroken deflated surface.

At 43 km, 105 m higher, climbing steeply, we come close to the inselberg, but because of our lack of water we dare not take the time to make a detour to visit it.

The fourth ridge, which is thickly covered with transported sand, does not exhibit the characteristic terracing and disintegration; since the deposits no longer include broad beds of clay, only

a few "Kanzeln" have been weathered out. Its southeastern part, which is much more extensively eroded, is also lacking in grotesque forms; it extends about 2 km, a gradually sinking table. At the 50.5 km mark we arrive at still another ridge lacking the steps and "Kanzeln"; cut by numerous rills, it resembles a typical bad-lands slope. At its foot however is a small maze of cones and hills, at the most 5 m high, consisting of reddish conglomerates (Rock Sample LXXXIV) in the upper strata and white sandstone (Rock Sample LXXXV) in the underlying bed.

At 55 km, 18.5 m higher, we climb the last abrupt precipice; it is relatively low and furrowed by numerous water channels. This is not another of the elongated ridges but the last escarpment in the "older" sedimentary deposits. The abrupt slope trends almost direct north-south, cutting directly across the deep sand of the caravan path. The path ascends via a gorge called Kusheh (Highway) by the camel drivers; since it is too narrow for the car, we make our ascent via a broad stream bed somewhat further north. Further upstream the bed is 8 m deep and filled with sand on the left side. Salt efflorescences begin to appear again. With considerable difficulty we climb over the steep bank of the stream and gain the edge of the table.

Hedin (76) observed of the Great Kavir that the boundary between the kavir soil and the firm ground is as sharply drawn as an ocean strand. The same is true of the kavir soil in the Lut. There are however various important differences between the 2. Whereas Hedin, Niedermayer, and Gabriel all agree that in the Great Kavir the polygonal salt slabs do not occur except in the inner desert, we found -- to our surprise -- that in the Lut these forms also

occur on the very edge of the desert. It has also been reported that around the edges of the Great Kavir the predominant rock is a yellow plastic clay which merges to flat salt areas; this is not true of the Lut. On the other hand, the phenomenon of alternating light and dark parts of the loam kavir observed in the Great Kavir also appears in the Lut. The darker loam in the Great Kavir was reported to be moister and of a greater consistency than the lighter, but we seldom found evidence to this effect in the Lut. Nor did we encounter salt crusts 1/2 m thick such as Hedin encountered in the Great Kavir. This difference obviously results from the difference in precipitation: winter rains, which occur commonly in the Great Kavir, are a rarity in the Lut -- a fact well attested to by the quantity of sand in the Tabasan Valley. Since there is less water here, less salt is dissolved, and the crust, which is formed in the process of evaporation, is limited in thickness. In addition, the salt slabs in the Lut are subject to a much greater extent to abrasion and deflation than those of the Great Kavir. Long-lasting summer storms such as occur in the Lut have not been reported in the Great Kavir; nevertheless there are extremely thin crusts in parts of the Great Kavir. Frequently enough we were made aware -- by the effect on our own bodies -- of the quantity of salt borne by the winds blowing out of the area of the polygons in the Lut.

Numerous streams and rivers (for example the Kal-i-Shaitan, which is 10-15 m deep) have been reported in the Great Kavir as well as numerous smaller streams which extend into the very heart of the desert and continue under the salt crust. In the Lut there is no known river other than the Kal-i-Shur. According to Gabriel (60) the flood plain of the latter is only 100 m broad, a good

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indication of the greater aridity of the Lut. To be sure, there are great catastrophic storms during which the water of the torrents streaming down from the 4,000-m mountains to the west runs as far as the heart of the Lut; but this does not happen nearly so often as in the Great Kavir. Indeed the eastern part of the latter is often completely covered with water for months at a time. There may be seasons when a salt lake forms in the lowest part of the Lut, but the fact remains that this desert is not only lower and hotter than the Great Kavir but also much drier.

We should like to emphasize that the core of the Lut is the deepest basin of the Iranian uplands. The elevation is given by Gabriel as 260 m, as "about 1,000 ft" on the English map; my figure was 280 m. It is possible that the lowest point is somewhat south of our route but I doubt that the difference could be greater than a few meters. The 120-150 m above sea level reported by Khanikoff is undoubtedly wrong. In any case it is amazing that one can read over and over again in the literature that the Sistan Depression or the Gaud-i-Zirreh is the lowest place within the Iranian border mountains. Even modern authors perpetuate this error.

In consideration of the low elevation of this basin one may well surmise that it is the hottest place on earth. I have dealt with this question in greater detail elsewhere (139).

Niedermayer calls attention to the fact that in the deeper parts of the Great Kavir gypsum does not occur. Gypsum, which is not easily soluble, is probably precipitated out early and is therefore found in the higher areas. Gabriel made the same observation: "the salt found in the lower areas of the kavir consists

for the most part of easily soluble common salt, whereas the less easily soluble gypsum is precipitated out in the higher areas of the salt marsh" (page 24). Different relationships prevailed in the Lut, or at least in those parts which I visited. To be sure, we also found salts in the heart of the desert but because of the greater aridity the gypsum appears even on the edges of the desert. The phenomenon of the coat of sand on the polygonal salt slabs, which was reported by both of these authors in the Great Kavir, also occurs in the Lut. It is transported sand held fast to the hygroscopic salt.

The kavir zones in the heart of the Lut are obviously drier than the Great Kavir. Hedin's perceptive statement to the effect that the kavir is actually a lake, the bottom of which is higher than the water level (77, I, page 247), does not appear to be applicable to the Lut. There are, of course, certain similarities in the constitution of the ground, particularly in the occurrence of clay beds and hard salt layers; but it is unthinkable that an iron bar would sink of its own weight in the Lut -- a phenomenon actually reported by Hedin in the Great Kavir (Camp XXVI). It is possible that the more southerly kavir areas of the Lut have a different character; nevertheless, it seems quite certain that the process of denudation is "more advanced," if one may use this expression, in the Lut than in the Great Kavir.

There are also interesting differences in the relief of the 2 deserts. Hedin describes the appearance in the middle of the Great Kavir between Camps XXV and XXVI of a terrace 3 m high followed by various ground swells such as are said to occur especially frequently in the areas at the edge of the desert. There is, for

example, the 1 1/2 m high Band-i-pil-i-chatle, or "Elephant Dam" as the fanciful Iranians have named it. Gabriel reports rounded bulges with gentle slopes resembling rolling dunes formations at intervals of as much as 500 m. Niedermayer reports similar phenomena. All 3 agree in describing these as the result of a tangential pressure acting on the viscous but labile kavir mass.

Aside from the small water channels on the edge (which create very modest relief differences) and the elongated ridges (which are in any case of a different constitution) we found only one important relief feature, a depression 200 m broad and at the most no more than one m deep. Just before we reached the eastern edge of the polygon kavir we finally came upon a terrace 1.5 m high. The rhomboid lines and the clay clod kavir cover it from base to ridge. It is hard to believe that this escarpment covered with rhomboid kavir, could be of tectonic origin, i.e., that it could be a fault scarp such as we observed on the edge of the desert (148), for it does not run in a straight line and even dies out in places. It does not seem likely that it is a sedimentary scarp constituted of the underlying conglomerates and sandstones; but on the other hand it would be hard to believe that in the formation of a fault scarp the land mass would be displaced without disturbing the rhomboid lines. In all probability the level of the kavir mass was once much higher. It sank and the rhomboids developed on all sides during or before the resultant contraction of the viscous clayey and salty kavir mass. This theory is substantiated by the fact that not far from the scarp a part of the underlying conglomerates projects hand-high out of the kavir, an indication of how thinly the latter veneers the bedrock: it represents only the surviving remnant of the kavir mass which existed prior to the

subsidence. The theory of a general lowering of the level is further substantiated by the fact that the kavir crust on the northern edge of the polygon kavir slopes more steeply than elsewhere.

The formation of the small basins within the clay polygon kavir is probably the result of vertical movements of the viscous mass. Gabriel gives a few examples of such movements. It is possible however that they reflect the relief of the surface beneath the kavir.

The "crater fields" are without doubt the result of internal stresses. They develop when the crystalized salt breaks through the already existent crust. The rhomboids apparently have no part in this process, since the clods of the loam or clay kavir develop independently of such rhomboid lines. Contrary to the views held by a number of authors, it is only in the salt slab polygon kavir that the upturned slabs follow the pattern already established by the polygonal lines.

Moreover we may say with certainty that the opinion held by some authors that the polygonal form of the salt slabs is connected with the tangential pressure exerted by slowly sinking masses of cliff debris, is erroneous. In the Lut the polygons frequently begin right at the edge of the "cliff" of the gravels and conglomerates where there are no masses of debris and where such are scarcely even imaginable. This of course does not rule out the tangential pressure, but the latter originates within each polygon as a result of the process of crystallization. Obviously such could not take place in sandy soil.

The Lut Desert presents good evidence of the deflational and corrosive effects of the wind. It is necessary to draw attention to this since we have been cautioned (107) against overestimating the denudational effects of the wind in these areas. I have described elsewhere (146) on the basis of my own observations the great violence and transport power of the storms in the Lut.

It goes without saying that the "older" as well as the "younger" sedimentary deposits must have filled the entire southern part of the Lut, for it is hardly possible that they could have been deposited only in places and on the edge only. Therefore both gravel series must have been transported by the wind. Precipitation may have played a part together with deflation in spreading it out.

In the moist ground of the Great Kavir the winds have but little effect. Hedin even goes so far as to call the wind "completely powerless" (76, page 267), a statement not to be taken too literally. But even in the summer when the kavir is dry it proves quite resistant to the wind. Niedarmayer who has the most thorough acquaintance with the area has reported this. Only the polygonal configurations of the rhomboid lines and the upturned blocks show unmistakably the effects of the wind, a fact also reported by Gabriel (60) in the Great Kavir. But the dry kavir is not wholly impervious to the wind. The kavir soil which constitutes the topmost stratum of the elongated ridges in the Lut differs from that at the foot only in its salt content and in the quartz (which we shall discuss later). These remnants indicate that a kavir must have formerly covered the "younger" sedimentary deposits which

filled the heart of the Lut; but, as the present state clearly shows, this kavir was not capable of protecting the underlying deposits from wind erosion. This phenomenon of disintegration into the ridges, mazes, "boulevards," and mushroom rocks, which we noted and which Gabriel discovered further south, does not occur in the Great Kavir. There is undoubtedly greater precipitation there and also less heat because of the more northerly location and greater elevation above sea level; but above all the Great Kavir is not subject to summer storms such as are common in the Lut. We shall demonstrate later that similar sedimentary deposits also exist in the Khurasan Kavir; but there they lie under a protective cover, whereas in the Lut they lie open.

Thus we arrive at the conclusion that the old kavir soil cover of the Lut Desert was not able to withstand the wind erosion because of the intensity of the storms and because of the lack of moisture which would have insured it against deflation. Incidentally it is not out of the question that these very summer storms might themselves be responsible for the high degree of aridity in the Lut. I have discussed this possibility elsewhere.

We know from observations made by various explorers that the saturation of the kavir is the result not only of precipitation but also of ground water. According to Hedin (77) the color of the soils depends upon the distance from the ground water table. At the time of our visit as well as Gabriel's the kavir in the heart of the Lut was dry, but we were told that there are times when the caravans have to make a detour because the regular path is so soft as to be impassable. Khanikoff (93) reported the same.

In consideration of these observations and experiences I have written elsewhere (147, page 147) that "in general in the basins of inner Asia the base level of denudation has been reached when a kavir is formed, i.e., when the process of denudation, at least during the damp seasons, approaches the ground water table." But the prerequisite for a kavir if it is not to fall to dust, is saturation with water, partially from above, partially from below. The latter is all the more readily possible in the kavir in the Lut, since the underlying "young" sedimentary deposits (the sands and conglomerates alternately bedded with clays) are well known as water-bearing forms. The existence of a ground water table in the Great Kavir has been proved; in places it actually lies above the surface. The idea that there is no water table beneath the kavir in the Lut is false (14). For if this were true, it would not have been possible for the kavir to form. The kavir is actually -- once again I am obliged to quote one of Hedin's perceptive statements -- "in a sense a disguised underground lake which contains more mire than water" (76, I, page 247).

If a kavir layer, to which sand and dust adhere during the moist stage, cannot rejuvenate itself, then it gradually falls victim to deflation. It was recently asserted (14) that today sand masses cannot pass through the kavir but this assertion is contrary to observed facts.

Gabriel writes of the kavir zone in the Lut: "the storm blows throughout the day. The sand which buries the kavir in places is driven along the ground in yellow clouds" (60, page 219). We observed sand fields in the kavir, especially on the leeward side of the elongated ridges; they found rest in only a few places

and save for their protected position these would also have been blown across the kavir. Niedermayer writes of the Great Kavir that the purity and coarseness of the sand is in direct proportion to the distance it has been transported across the kavir, for the dust and fine sand are held fast on the kavir hygroscopically. Hedin who was the first to point out the law governing sand accumulations in the south of all the inner Iranian basins, also states that the stage in which a lake may be does not play a decisive role in the question of sand transportation: "the lake may be living or dead, there is drift sand in any case" (I, page 188). This is to say that sand will be transported across the basin whether it is filled with water, kavir, or rock.

D. To Deh-Salm via the Surkh-Kuh

Once we had reached the plateau the greatest danger was behind us, for if we had not been able to get over the escarpment with the car we would have had to walk to Deh-Salm; considering our thirst, it is doubtful that we would have made it (137). We stand now on a new level about 100 m higher built up of eruptives; it slopes gently to the north, marked by a few shallow depressions. The sedimentary table merges to it without any apparent break. We had noted pebbles of eruptive in the stream bed by which we ascended, but because of our difficulties in finding a way out of the walled-in "prison" of the heart of the desert and because of the haste necessitated by the approaching darkness, we had no time to investigate. Gabriel, who took the direct route to Deh-Salm through the Kushe Defile, was also in great haste and was not able to make any observations from which it would be possible to analyze the transition from the sedimentary deposits to the eruptives.

We soon came upon a path leading NNE. Since according to our sighting it should lead to the Kuh-Surkh where we hoped to find water, we followed it. As it turned out the path did lead to the Kuh-i-Surkh, but not to water. Driving on a course of 330° we cross a few stream beds running to the right, cross a stretch with softer ground covered with salt efflorescences and strewn with gravel, pass 3 small hills with sand-covered slopes, and arrive at a stream bed full of fine yellow gravel. Since the rising dunes make driving after dark dangerous, we head toward the slope of the Pushteh-i-Jaghvir across a flat desert floor with a gruss mantle with furrows containing salty sand. We pitch Camp 50 at the foot of the mountain, where we are somewhat protected from the approaching storm.

Throughout the day there had been short, violent gusts of wind bringing noticeably hot air, sometimes from the west, usually from the south. At 2100 hours the wind began to blow steadily from the south, rising periodically to gusts of such violence that our camp was buried under sand, gruss, and even stones as much as 4 cm in diameter, forcing us to take shelter under the car. Usually the winds in the Lut tend to die down during the night, but this storm continued unabated all night long. Between 2100 hours and 0600 hours the aneroid fell from 711 to 698.5°. To be sure, there was probably some lag at the time of the evening reading, due to the fact that we had climbed some 150 m in reaching the mountain; nevertheless the big drop indicated the nearness of a depression. The temperatures also changed abnormally. At 2100 hours the reading was 24° C, only 9° less than the maximum in the heart of the desert, and the night did not bring any perceptible cooling off. At 0600 hours on 27 March the reading was 20°. The wind continued

with unabated force but the direction had shifted to ESE. It was so violent that when I undertook to climb the mountain I had to creep on all fours and during the stronger gusts press myself flat and cling to the rock. My description of this has been published elsewhere (146).

The next morning as we climbed toward the jagged ridge of the Pushteh-i-Jaghvir we found that we were on a higher level. The 10 km from the edge of the plateau is an almost perfectly flat area broken only by isolated inselbergs or hills and ending at the Pushteh in a rolling area 150-200 m higher. The storm and murkiness deprived us of a clear view. The mountain itself exhibited a light pink quartz porphyry with kaolinized feldspars. Along the jointing, which strikes 130° and perpendicular thereto, the rock shells off in plates. Numerous such plates a centimeter thick and as much as 25 cm long, lay as a sort of protective cover over the sand on the interstream plateaus. The first signs of vegetation appeared in the erosion channels of the mountain. The plain at this point was still wholly barren of vegetation.

We soon come upon the path we had lost the day before and hold to it, traveling northeastward through swirling sand. The 3-peaked Pushteh-i-Jaghvir on our right drops away to a few gently sloping foothills on our left. We cross this uplift and proceed down the gently rolling slope on the other side. The desert pavement here consists of gruss and smallish clastics (up to egg size) covered with sand. There are numerous sand ripple marks. About 5 km away is a chain of hills with numerous peaks. Its spurs on our right are also constituted of quartz porphyry; they are almost buried in sand and rubble. Small dunes appear frequently, their

ridges up to 50 cm high running at 110°. Many are crescent-shaped. They were apparently formed by winds from the NNW. To the left are a few inselbergs.

After a short climb we arrive at another plain, the flatness of which is broken only by barely perceptible swells and basins. The Kuh-i-Surkh towers high over the plain. We head toward the latter, driving across the gruss dunes which are widely dispersed here. We cross a ribbon of sand running from east to west, the first stream bed we have encountered today. Soon we come upon the bluish gray, coarse waste familiar to us from our previous visit to the Kuh-i-Surkh. Another 3 km and we pass by this mountain at a distance of 1-1.5 km, cutting diagonally across its stream beds and gullies, which are shallow but steeply banked. Desert plants grow in these beds at intervals of about 30 cm; here and there, where the banks are free of gravel, salt efflorescences appear. We cross a broad river bed with sandy banks and then additional rills which cut the path as well as the foot of the Surkh-Kuh into numerous ridges. Soon we reach the place with the 3 graves familiar to us from Route I. A rich vegetation grows in the coarse waste here.

We cross the wide, sandy river bed, also familiar to us from Route I, cross a number of low dunes, and, in order to reach Deh-Salm by the most direct route, turn left and drive downstream in the river bed proper. At the time of our earlier visit we had found this bed soft and muddy, but now the bottom is firm, covered with sand and small spots of loam and clay as well as loam clod kavir with salt efflorescences. A brown clod kavir also appears here and there on the low banks. The bed is as much as 100 m broad

in places. After 3 km we leave the river bed and drive across a number of shallow basins with floors of hard loam clods; the rims are strewn with pea-size gravel. We then drive over a smooth, gently sloping plain with numerous gruss ripples covered on the gradual slope with sand. The ridges run northeast-southwest. After crossing 4 stream beds with a few halophytes we come to a flat area of fine gruss in the process of forming dunes. Not being able to find the caravan path, we turn around and follow our own tracks back to the 3 graves at the Kuh-i-Surkh. From there we follow the route to Deh-Salm described in Route I. With our last strength we reach Deh-Salm just before darkness.

Because of the storm and the poor visibility as well as the necessity for haste, we were not able to make very thorough observations along this part of the route. We cannot therefore enlarge very much on the foregoing.

Particularly significant is the drop of 150-200 m at the Pushteh-i-Jaghvir from the higher level to the lower, the latter broken only by isolated inselbergs. Is it an en echelon fault? or perhaps an abrasion terrace on which the "older" sedimentary deposits formerly lay? At the present time it is impossible to say. But it should be noted that on our way to the heart of the desert at about the same elevation (550 m) we came upon a plain which with only slight difference in elevation was also dotted with inselbergs. This route lay some 50 km to the west.

The gently rolling terrain appeared to rise another 100 m before we reached the Kuh-i-Surkh. But here again we were not able to make wholly reliable observations and therefore cannot say definitely.

The quartz porphyry apparently extends over a great area. The same rock was reported by Gabriel (60) in the same state of exfoliation in the hills Do-Shahil, 15 km to the east of our place of discovery.

The traces of strong deflation are apparent everywhere along this section of the route. The intensity of the storms is evidenced by the fact that there is almost no sand here. Even the gruss has been formed to dunes or ripple marks. Beyond the Kuh-i-Surkh the terrain is dissected by streams, but the numerous undrained basins indicate that the wind plays a greater part in erosion here than water.

Deh-Salm was described in Route I.

ROUTE IV. FROM DEH-SALM TO KARIMABAD

A. To Basiran

There is actually no road leading north from Deh-Salm but the stretch is traveled on occasion. Stone markers have been set up only here and there and these are quickly washed away by the water streaming down from the Kuh-i-Shah, so that we have to seek the way as best one can by keeping in view certain landmarks, in particular the Kuh-Bishe. The first section of the way leads over a gradually rising plain, actually the alluvial deposits of the mighty Kuh-i-Shah, which towers 1,500 m higher. This stretch, dissected by innumerable erosion channels, often presents a monotonously unchanging picture. For lack of a better basis, we shall divide it up according to the distance from Deh-Salm.

(a) 0-10 km beyond and 0-40 m higher than Deh-Salm: we seek the way among numerous deflation hills up to 50 cm high overgrown with saltwort, and over barrens of white, coarse gravel. In the first half of the stretch the sand has been blown away, leaving only gruss, but in the second half we find sand and gruss together unsorted. The fine grained sand predominates, crusted by silification and frequently in clod form. It also fills the beds of numerous streams coming from the NNE. These beds, unlike the others, contain no vegetation. Probably they have not contained water for a long time and the sand has killed the plants. The silification occurs here to a smaller degree. In Deh-Salm this entire area is called Gaud-i-Dehbak (Basin of the Upper Village). The name probably indicates that in the golden age of the oasis the old Deh-Salm was located here. The peaks 2 km to the west, wings of the Kuh-Rigi, are called Kuh-i-Dehbala (Upper Village Mountains).

(b) 10-20 km beyond and 40-65 m higher than Deh-Salm: we drive directly NNW toward the Mian-i-Dasht (In the Midst of the Desert), a 2-peaked island hill about 30 m high. The gravel, which usually appears on the higher places in long, broad strips, begins to appear also between the stream beds. The sand on the other hand is usually in the stream beds or in shallow basins at lower levels. Toward the end of the stretch we come to a small rise in the terrain, apparently an erosion residual of the Mian-i-Dasht. The quartz here is engulfed in reddish gruss and rock fragments up to the size of an egg. The streams running from the NNE contain a few growths of desert plants and low saxaul. A little saltwort grows at intervals of about 10 m on hummocks in the sand. The gravel areas are still barren of vegetation. Beyond this point we frequently see hares, gazelles, and bustards (called Duhdari) and other birds.

(c) 20-30 km beyond and 65-145 m higher than Deh-Salm: at the foot of the second peak of the Mian-i-Dasht we break a specimen of grayish green quartzite (Rock Sample LXXXVI); but as we proceed north and NNW we come again to the reddish gruss and to rock fragments up to the size of a child's head consisting of a light and black quartz. The ground, which slopes perceptibly upward here, is covered with this material in increasing quantities. The surface is intensively dissected by stream beds incised as deep as 30 cm, now coming from NNW. At the foot of the Mian-i-Dasht we had found only young shoots of the desert plants, but here the entire area, except for bare rocky places, is densely overgrown with mature bushes. To the right, almost parallel to our path, is the 500-m high chain of the Suriha Mountains. (So called on the map; these mountains were called Lurikhan by the local inhabitants.) This chain constitutes the first foothills of the Kuh-i-Shah; with their reddish color they are in sharp contrast to the 2 other much higher spurs and to the main ridge itself.

(d) 30-40 km beyond and 145-190 m higher than Deh-Salm: we cross the alluvial fan with its distinctive features. It is built up of fanglomerate, beneath which rubble of black quartzite up to the size of a child's head predominates. Salt efflorescences appear again on the barren, gravel-strewn spots, evidence of moisture in the ground. Since the stream beds running NNE from the Suriha Chain are as much as 50 cm deep and steeply banked, we detour to the west where they are shallower. Where the broader beds contain sand there are deflation hills 20-40 cm high, evidence that deflation plays a part as well as erosion in the deepening of the beds. The fanglomerate surface on the alluvial fan proper is resistant to the wind, but the loose sand in the stream beds is highly

susceptible to wind action. For the first time the slopes of the banks exhibit kavir formations consisting of a ripple-marked loam soil powdered with salt. The vegetation is more abundant here than on the previous stretches. There are heavy growths of halophytes and isolated but tall Kelakunda plants, a favorite pasturage of the camels. Its blooms grow out of heads similar to asparagus tops, much in the manner of common mullein. To our right the Suriha Chain comes to an end, falling away to plain via a few foothills. The foot exhibits one to 2 levels and salt efflorescences.

(e) 40-50 km beyond and 150-190 m higher than Deh-Salm: we cross a broad ridge and then drive downstream in the bed of a shallow stream running NNW. Its pebbles are usually of dark quartzite, occasionally of limestone and sandstone; there are gypsum efflorescences on the slopes of the banks. After 2.5 km the gradient becomes less steep and the stream subdivides. We drive for 3 km across a long, low rise in the terrain and across an area of dark gray, coarse gravel (up to the size of an egg) till we reach another broad stream bed which runs N and NNW. But the tall saxaul in the bed often chokes the passage so that we are obliged to return to the rock-strewn barrens; where there is gruss the ground is frequently soft. We pitch Camp 52 at the edge of the stream.

As we left Deh-Salm at 1000 hours there were small cirri in the sky and a gentle wind was blowing from the NNE. The temperature was 16° C but the thermometer climbed 4 to 5° as soon as we had left the coolness of the oasis and entered onto the alluvial fan. The midday temperatures fluctuated between 23 and 25°. The air was unusually hazy and remained so throughout the afternoon,

during which the sky became completely clear as a light wind blew from the northwest. Not until about 1600 hours did the visibility improve; that evening the usual clearness predominated. At 2100 hours on 29 March the temperature was 17°. On 30 March the temperature reached the low of 12°; the sky was overcast and the wind from the east. The atmospheric pressure also fell somewhat overnight. At 0700 hours the thermometer had climbed to 16°. At 0900 hours a strong east wind pushed strati and cumuli-nimbi over the Kuh-i-Shah.

Because our time was limited by financial considerations we were not able to undertake a climb of the Kuh-i-Shah, although such a climb would certainly have yielded valuable information and permitted excellent views over the surrounding area. We had to be content with observations made from a distance of about 5 km.

The Kuh-i-Shah consists of 4 wing-shaped steps trending NNW-SSE, the lowest and southernmost of which is the Suriha mentioned above, while the highest and northernmost is the Kuh-i-Shah proper; the elevation of the latter is given on the map as 2,730 m. This high northern part is clearly recognizable as a sedimentary table tilted about 15° to the north, the steps of which lend the northward sloping crest a jagged appearance in places. The abrupt slope which falls away to the south from the highest point may, so far as we could tell with the telescope, also be a sedimentary scarp. The crest continues from there southward at a more or less uniform height, then with a few saddles falls away by steps. We were not able to determine the nature of the rock. The pebbles in the stream bed consist of limestone and sandstone, but also of quartzite (Rock Sample LXXXVII). In the low, reddish brown foothills we suspect the presence of young conglomerates such as we

found at the Bakhtu, an assumption substantiated by the large quantities of gravel. The fact that the beds on the margin are all vertical tends to confirm our assumption (based on the morphology) of an en echelon fault. To the west there are 3 smaller mountain chains en echelon between the Kuh-i-Shah and the Abdullahi. We assume that these are the same 3 en echelon faults we observed at the Kuh-Abdullahi (Route I). Therefore the basin of the Lut apparently sinks in step faults which can be traced as far as the Kuh-i-Shah.

(f) 50-84 km beyond and 215-565 m higher than Deh-Salm: we drive uphill toward the double peak of the Kuh-Bishe, now headed 40° across stream beds, now 10° across barrens covered with rock fragments up to the size of one's hand. The vegetation consists largely of artemisia herbs. Before us to the left is a small chain of hills with 2 predominating peaks which the camel drivers call Do-Beradar (Two Brothers). They do not have the table form which characterizes the Kuh-i-Shah, rather a silhouette such as one finds in eruptives. Eleven kilometers beyond our camp, after a difficult drive across the dissected pediment of the Kuh-i-Shah, we come to a 200-m broad compound river bed. We follow it upstream for 7 km NNW.

The river is extraordinarily incongruously constructed. The deep channel is along the right bank, which is usually steep, sometimes even vertical. The bank on the left is so low that the river occasionally feathers out into erosion channels on that side. Small plants grow in strips in the river bed, white anemones and miniature daisies; saxaul frequently appears in the beds of the inflowing streams. Apparently the large water masses which collect here do

not permit the growth of ligneous plants. The discongruity is probably so pronounced because of the especially high deviation coefficient (per Baer's law on deviation to the right) resulting from the steep gradient of the downrushing streams. Where the spurs of the Do-Beradar reach the river we find a dark eruptive (Rock Sample LXXXVIII), which confirms what we had already assumed on a morphological basis. Four to 5 km away is a 3-peaked chain of hills of the same coloration and form trending west; it too is probably constituted of eruptives. The steep bank of the river is now formed by a few ridges from the Do-Berader. They join to form a single level which extends for some distance along the slope. Below along the river itself, are 2 terraces.

Leaving the river we stand before a new type of landscape. A mountain chain up to 300 m high extends from the northern spur of the Kuh-i-Shah to the borders of the Lut Desert proper, to Sar-i-Chingi and Chah-Isma'il; it constitutes the boundary of the alluvial plain. The numerous peaks exhibit a remarkable uniformity of height; only isolated higher mountains jut up over the common level. The most characteristic of these peaks are the Kuh-i-Dehnou (New Village Mountain) (325°); the Kuh-Andjira (so called because of its wild fig trees) (346°); the Kuh-Bishe (toward which we are headed); the Kuh-Gemish (9°); the Kuh-Mollah-Hussein-Ibrahim (17°); the Kuh-i-Gabrestan (59°); and finally the Siah-Kuh (Black Mountain) (73°). The Kuh-i-Gabrestan, an especially outstanding peak, would appear on the basis of its name to have been a burial ground in pre-Mohammedan times. One is struck by the fact that the hills end right at the pediment of the Kuh-i-Shah; only a few isolated peaks jut out of the latter. There is probably a connection between these phenomena, but our observations were not extensive enough to allow a definite opinion.

We drive toward these hills in a new stream bed with 40 cm banks on either side; tamarisk grows in the bed in addition to large quantities of saxaul and artemisia. There are pebbles up to the size of a child's head on the plain. The vegetation suddenly becomes scanty and stunted, so abruptly that we suspect a change in the nature of the rocks, but because of the fanglomerate we cannot tell for certain. We enter the hilly area via still another river bed, 60 m broad. At first we encounter the grayish green eruptives mentioned above and after a kilometer they appear outcropping in the river bed (Rock Sample LXXXIX). Later the bed leads by a dove-gray limestone with veins and faults with 70° strike. There are dense growths of tamarisk, frequently over 2 m tall, along the banks. Still later the river cuts into light colored sandstones with breccia zones strongly discolored by iron and fault zones striking 40°; it then enters into serifizierte light eruptives. After a time the tamarisks grow so thick that we are obliged to drive on the soft terrace which lies 5 m above the bed; it consists of sand under a thin gravel covering. On the slope are strips of rippled sandy loam soil powdered with salt.

The village Bishe, 200 m east of the river bed, consists of only a few mud huts. These are built by digging a circular hole about 80 cm deep and roofing it with tamarisk wood covered over with earth. One enters these houses, which are actually only stationary tents, by descending a small set of steps cut in the earth and passing through a door barely 120 cm high. At this time the village is inhabited by only 4 men, 2 women, and one child, since the other 50 inhabitants have already taken the cattle to the Kuh-i-Shah Mountains where they will live in tents. Such bare necessities as wheat, millet, beets, cotton, and vegetables are raised in

carefully fenced fields, since these poverty-striken people cannot afford to lose any part of their crops to the wild animals in the area. There is a small qanat for irrigation. Interestingly enough, it passes under the nearby loam kavir without desalinifying it or itself becoming salty.

Nowhere in eastern Iran did we see a more impoverished settlement than Bishe. Nevertheless it has an outstanding feature: usually the villages with qanats are inhabited by tenant farmers, for the people are not able to raise the capital necessary for such irrigation installations and have to borrow it from the well-to-do landowners; but the inhabitants of Bishe have managed to construct their relatively short qanat with communal labor and without outside capital. They were probably encouraged in this undertaking by the fact that cultivation has become more profitable as a result of the increase in commerce and the greater opportunities for selling cotton. To be sure, they still gain the greater part of their livelihood from cattle breeding. It is on this account that they go into the mountains at the beginning of the new year, i.e., on 21 March.

(g) 84-102 km beyond and 435-560 m higher than Deh-Salm: above us to the northeast towers the Kuh-Bishe, built up of hard yellowish brown, somewhat porous limestones. This rock, folded and broken by faults, constitutes the key horizon throughout these hills. The thick head of the Kuh-Gemish, before us to the left, is made up of the same material striking 40° and dipping $40\text{-}70^{\circ}$ to the north. So far as we could tell, the inclined tables of the Kuh-i-Shah are probably also constituted of such limestones.

On the way back to the Rud-i-Shandik we drive over a kavir, in the lower spots of which there is firm sand and vegetation, particularly saxaul. Apparently the rainwater which collects in the deeper basins here has desalinified the soil. The river bed is 100 m broad in places and as much as 2 m deep. Here and there the banks are blown over with sand. The debris, about the size of one's head, contains in especially large quantities an eruptive with white plagioclase (Rock Sample XCIV).

Further on broad areas are filled in with conglomerates as much as 30 m thick, probably river-laid deposits. The younger and finer terrace gravels are embedded in these older, coarser gravels which include fragments up to the size of one's head. The river becomes narrower and 1/2 m shallower and we enter upon dark andesites (Rock Sample XCI) which lie over the hard, porous limestones mentioned above (Rock Sample XCII). The old conglomerates, which consist mostly of the eruptives mentioned above, are disintegrated here and there, forming small hills. The latter are covered with a weathered crust. The river runs through a small syncline where the floor consists at first of limestones, then of the eruptives, then of the horizontally bedded conglomerates and terrace gravels. Further on we come upon an outcrop of the eruptives with plagioclase which we had noted so often among the pebbles and an outcrop of dark green eruptives (Rock Sample XCIII).

Seven kilometers before the site of our overnight camp we leave the mountain tract and enter a cauldron with numerous hills, above which tower a few mountains. Kavir formations appear here and there on the slopes of the river banks; the light green eruptives with plagioclase also appear frequently. In the bed itself,

which is about 50 cm deep, tamarisks grow up to a meter high. Further on the bed contains dead brackish water, probably collected rainwater. Eventually we reach the head, numerous shallow erosion channels in a sandy kavir lightly powdered with salt. The kavir merges to a rankly overgrown semidesert with many barren heights. This in turn gives way to a loam kavir. We pitch Camp 53 at the edge of the semidesert.

The 10-km broad mountain tract we have just traversed is sharply folded and broken by faults. The thick, hard bed of porous limestone was able to withstand the tectonic forces, but the subjacent sedimentary rocks, the sandstones and argillaceous limestones, underwent intensive folding, resulting in radical variations in the direction of dip. One mountain, called Klippenberg [Crag Mountain] in our route notes, had vertical, or almost vertical, beds grouped in a fan shape which formed a jagged, crag-like crest. Another exhibited 2 strata complexes with distinct characteristics and attitude of bedding, separated by an almost vertical fault trace. Older formations which were already folded must have been covered over by younger ones (the key horizon) which were themselves subsequently subjected to folding and later, after the volcanic effusions, to intensive block faulting. This period of block faulting must have preceded the deposition of the conglomerates, since the latter are not tilted. Thus the underlying beds were subjected to folding which continued after a transgressive overlapping of the limestones. This was followed by an eruption of the lava which we can place at the end of the Cretaceous or the beginning of the Tertiary (3). At the same time, and also subsequently, these fold mountains were subjected anew to tectonic disturbances in which they broke in block faults.

Since the older conglomerates and the younger gravels were not disturbed in this process, it seems likely that their deposition can be equated in time with those in the Lut, i.e., the latter with the last and the former with the next to last glacial stage.

The occurrence of these thick gravel deposits here is surprising in itself. The Rud-i-Shandik has its source only a short distance away and therefore could not have brought them here, not even the younger gravel. It is possible that the source of the river was formerly much further north. This theory is supported to a certain extent by our observation from Camp 53 of a large compound river which has cut a gap through the chain of hills to the east; in the process it may have robbed the Shandik of its upper course. This interpretation of the gap remains problematical, but it would simplify solution of the whole problem of the eastern boundary of the Lut.

The weather on 30 March ran an interesting course. The east wind which sprang up early increased in intensity throughout the morning. At noon it shifted to the south and the sky became overcast with rain clouds. A few drops fell at 1345 and 1400 hours, but for the most part they evaporated before they reached the ground. Between 1000 and 1315 hours (shortly before the first drops fell) the temperature rose from 18° to 22°; it then fell irregularly, reaching 15° at 1600 hours. By 1815 hours it had fallen to 6° and shortly thereafter there was a short but heavy rainfall. After the rain the temperature began to climb again, reaching 16° at 1900 hours. At this time there was a gentle southwest wind. These extraordinary temperature changes can only be explained by an inversion. In the afternoon the aneroid fell by about 10 mm,

a phenomenon hardly to be accounted for by a lag, since the differences in elevation were modest and we had made lengthy pauses along the way. At 0600 on 31 March there was wind from the east, the sky was overcast, and the temperature was 10°, the minimum for that day. At 0800 there was a slight wind, the skies were clear, and the temperature was 14°.

We had pitched camp in the dark. In the morning light the camp site is revealed as a semidesert with growths of artemisia. The terrain, slightly dissected, slopes gently to the east. On the "heights," along with the characteristic rock pavement, are the familiar bare spots with clastics up to the size of one's hand; violet-colored dwarf poppies and yellow shepherd's purse bloom in small, moist rills. In the north a few fairly high hills with sedimentary rocks dipping slightly to the east and a number of larger mountains, e.g., the Kamar-Siah, Kamar-i-Burdj, and the Chah-Surd, merge to a subdued ridge intensively dissected in badlands fashion. The latter, which exhibits a striking uniformity in the height of its crest, is bounded in the east by a gap. It is followed by the mountain tract we passed through yesterday. The characteristic key horizon of hard limestones forms numerous crests with various directions of dip. Five hundred to 1,000 m to the west, this side of the jagged crest line of the Kuh-Andjira, is a chain of hills apparently constituted of eruptives. The Kuh-i-Dehnou lies ENE.

We cross several small stream beds with the cut banks, about 75 cm high, facing north. Salt efflorescences and kavir flecks appear frequently on the bare heights. We come to a sand kavir and the vegetation, which had included even ligneous plants

in the stream beds, becomes sparse. We drive slowly uphill, NNE, in a dry bed with rich growths of tamarisk, passing a second, higher kavir on our left. The bed is almost 100 m broad. It receives a few tributaries from the left, then meanders between terraced hills of light gray limestone with 130° strike and slight dip to the north. Further on there are numerous spots of moist sand among the low tamarisks. We encounter banks 3 m high of light colored, hard and dense sandstone striking 140° and dipping 70° to the northwest. Two kilometers farther the direction of strike has not changed. Right and left of the firm river bed the intensely dissected plain, covered with clastics up to the size of a child's head, slopes gently uphill. The river bed soon subdivides into several channels about 3 m deep and broad. The loess through which they lead is deposited at the foot of low hills, out of which reddish brown walls have been weathered.

Here, 11 km before Basiran, we reach a high spot in the hilly area. There are kavir formations on the bare heights. In the southeast are the characteristic purplish-red solitary peaks of the area around Qal'eh-Seri, our goal for the morrow. We drive downstream in a narrow, winding river bed about 50 cm deep; it contains abundant vegetation. The bed is made rough by boulders twice the size of one's head from the small nearby hills. After 3 km we reach a flatter terrain where tamarisk grows. Here we find basaltic eruptives along the left bank. We leave the bed and drive along a terrace, then cross 4 small chains of hills with basaltic talus and arrive at a broad, barren stream bed. We cross it and move on to Basiran.

This section of Route IV provides us with insights into the nature of the area along the eastern margin of the Lut. Apparently the East Iranian Mountains between the Lut and the Meridional Highway are cut by various grabens accompanied by en echelon faults. In the first graben (through which the highway itself runs) is the basin of Neh. To the west, parallel to the basin of Neh, is the valley depression Sehluh, which we followed out of Neh (Route I). Still further west is the plain of the Gaud-i-Neh, followed by the valley depression of Deh-Salm. The latter is bounded in the east by the Shah-Kuh and its southern spurs and in the west by the mountain system of the Kuh-Abdullahi and its associated peaks. The en echelon faults are readily observable at the Kuh-i-Shah and can also be observed at the Kuh-Abdullahi.

The problem of the geological substructure remains unclarified. It is possible that the gruss on the surface indicates the presence of granite or granodiorite such as we observed in the area of Deh-Salm. The quartzites of the island hills of Mian-i-Dasht would be erosion residuals according to this interpretation. But it is entirely possible that the large quantity of gravel, reddish sands, and egg-size quartz stems from conglomerates, of which the Suriha Chain is probably constituted. In any case the Kuh-i-Shah is to be regarded as a tilted sedimentary table. Its dominating heights can only be explained in terms of tectonic movements, namely, block faulting along east-west tectonic lines. We established this direction frequently. The intensive folding in 2 different epochs, the volcanic effusions, and the final block faulting (which can be observed in particularly instructive form in the mountain tract of Bishe), all bear witness to the fact that we are dealing here with an area under great tectonic stress.

As a working hypothesis we should like to suggest that the East Iranian Mountains were linked and then compressed into the direction of strike indicated above. The direction of strike 130-140° which we noted repeatedly and which some of the valleys follow, was disturbed by the meridional faults. The more recent tectonic movements have turned the old directions around.

The older conglomerates were not disturbed by the tectonic movements. They are constituted of river gravels and the river with its younger gravels is embedded in them. Are we dealing here again with the "older" and "younger" sedimentary deposits? This theory is supported by the fact that here in this area of great tectonic movements the conglomerates are no more disturbed than are elsewhere the "older" sedimentary deposits. Of course we cannot explain why these conglomerates suddenly cease near Bishe. The loess, which like that of Hamund was of slight thickness and extent, was limited to the southern slopes of a few hills.

Finally a word about the case of stream capture. We did not investigate this phenomenon in detail. We were able to determine only that the upper course of the Shandik had been tapped and the water led off to the compound river of the Gaud-i-Neh. This explains the occurrence of the coarse gravel as the deposition of a river formerly much longer.

This section of the route also provides us with instructive examples of the tendency of the vegetation to increase with increasing elevation. As we pointed out in Route I, Deh-Salm is not far from the boundary of the Lut, the desert wholly barren of vegetation. All along the upslope stretches of the route we noticed a gradual increase in the quantity and variety of the desert plants and

ligneous plants. Of course in the area around Deh-Salm the vegetation has been considerably reduced, since the inhabitants collect dried desert plants and twigs for kundae (firewood). The heaviest vegetation is in and around the streams which most often contain water. In a few places along the route the tamarisk bushes were from 2 to 2.5 m high and grew so close together that we could not pass with the car. These trees managed to survive chiefly because of their remoteness from human habitation, but like the "forest" on the other side of the Kuh-i-Shah, they were probably once even more numerous, thanks to the greater amount of water drawn from the atmosphere in the vicinity of this 2,500 m mountain. Their former greater extent is also indicated by various place names in this area. The copper mines which we shall encounter later undoubtedly played a considerable role in the deforestation. It is significant that as one approaches the populated areas to the north the ligneous plants disappear.

This part of the route is particularly interesting from the socio-economic point of view, since it runs along the edge of possible human habitation. The roots of Deh-Salm are in commercial traffic. Bishe on the other hand is the outmost village on the edge of the desert to support its inhabitants from farming and cattle breeding. In many parts of the fringe areas the population is pulling back from the edge of the desert (a phenomenon in which opium addiction plays no small role), but Bishe actually represents an advance. The inhabitants are former nomads who decided to settle down. They were able to construct the necessary qanat by themselves, since there is ample ground water and seepage water in the vicinity of the Kuh-i-Shah; the deep shafts and long tunnels which ordinarily require a large initial capital were not

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necessary here. Their settling down was undoubtedly encouraged by the complete political and economic change which I have treated in detail elsewhere (138). The new security, above all else, has enabled the people to build new settlements on the edge of the Lut. All the other permanent settlements which we visited were protected by castles and walls or other special defensive installations (except those like Deh-Salm which were treated as "open cities" because their existence was as important to the robbers as to the inhabitants). Then too, goods which were formerly almost unsalable are now brought into the trade by the new motorized caravans; these new marketing possibilities have entailed a certain amount of economic planning. And, last but not least, the nomad declares of himself, "Hitch dud namikasham" (I do not smoke), by which he means primarily that he does not smoke opium. This addiction has done more damage than any of the epidemics or famines, for the latter are ephemeral whereas the opium pipe is a constant source of evil. Even if these new farmers do not survive the various catastrophes here on the edge of the Lut, they have made an encouraging start on their own initiative. If the same effort were made elsewhere along the edges of habitation in Iran, there would be a considerable promise of general success.

B. From Basiran to Qal'eh-Seri and Back

The village of Basiran has about 80 houses and 400 inhabitants. Khanikoff (93) visited the place but makes no report on it. It is governed by a representative of the city of Neh. There is a holy grave, a bath, and a noteworthy refuge castle which has fallen to ruin, as have all such castles in eastern Iran since the Baluchi have ceased to constitute a threat. The gate of the castle consists

of a huge millstone, for the robbers once succeeded in gaining entrance by burning the wooden wings of the gate. The small houses and stalls within the fortress served to protect the herds and children while the adults were engaged in holding back the enemy. The men manned the towers while the women manned the throw holes and tar channels over the gate. The defenders were supplied with water from a spring which has subsequently fallen to ruin.

Fruits, primarily peaches, are raised in a few orchards. Field crops are also cultivated. In the fields irrigated by qanat the people raise wheat, millet, cotton, and a few vegetables, but they live primarily by cattle breeding. From 21 March to 15 May (when the wheat is harvested) only the few people charged with tending to the irrigation remain in the village. All the others go into the mountains with the herds, where they tend the young animals, prepare cheese for the winter, and shear the sheep. Their chief income is from the sale of wool. Formerly when the mines of Qal'eh-Seri were still working, Basiran gained considerable extra income there. For a time a few men even undertook copper smelting on their own; the product, which was quite primitive, brought 26 rials per man. Several houses in the village are constructed of a mixture of loam and slag.

Wool is worth only 15 rials per man; seed cotton sells for 6-7 rials per man. (One rial = 20 Pfennig; 1 man = 5.9 kilograms.)

According to the inhabitants, the following villages are to be found in the area of Basiran; for the most part we did not check their statements.

Sector	Name	Kilometers From Basiran	No of Houses
North	Kamar-i-Sabs	3	6
North	Mehmedabad	5	4
North	Domruba	5	4
North	Aghbari	8	1
North	Sharafi (Shurfe according to Hedin)	10	1
North	Hiret	15	4
East	Dehnou	25	40
East	Rahne (Rome according to Hedin)	30	15
East	Meigan (Meighoun according to Khanikoff. He found an intensity of cultivation here equaled only at Isfahan.)	30	100
East	Hammunch	30	5
East	Kelat-i-Sheikh-Ali	40	2
South	Domruba	18	2
South	Atesh-Karda (Khanikoff reports a hauz of the same name between Karimabad and Ambar.)	50	5
South	Surkh (to the east of the Shah-Kuh)	50	5
South	Rad-i-Gor (to the east of the Shah-Kuh)	?	8
South	Kelateh-i-Reis (to the east of the Shah-Kuh)	?	8
South	Rahne (to the west of the Shah-Kuh)	45	15
South	Deh-Murgh (to the west of the Shah-Kuh)	50	20
West	Aliabad	2	8
West	Khulgabad	5	6
West	Qal'eh-Seri	25	6

We made a side trip to Qal'eh-Seri on foot, leaving the car in Basiran while we were waiting for fuel ordered from Birdjand. Our observations made in Qal'eh-Seri between 2 April and 7 April have already been written up, but one copy was given to the Iranian government and the other was burned. Therefore our information is not complete, but at least the map remains (see Sketch 19). Qal'eh-Seri was visited by Goebel, the geologist in Khanikoff's expedition, who brought back the first reports on the old mines there. I am not familiar with his sketches. According to Khanikoff's report there are to be found there "des chambres des mine, des galèries spacieuses de dimensions colossales taillees dans le roc vif." He reports that copper, lead, manganese, and turquoise were produced. The local inhabitants told him that the mines date back to the time of the Arab conquest, but Khanikoff doubts this, since none of the Arab geographers mention them. He is inclined to believe that they were begun in Sefividen times and abandoned because of the Baluchi danger. Sykes knew Qal'eh-Seri also by the name Qal'eh-Bagr (Castle of the Fire Worshipers); he takes this as an indication that the origins of the settlement go back to pre-Islamic times. When he visited the mines at the end of the last century they were still producing 3,000 kg of copper a year. At the time of our visit nothing was left of the mining installations he reports except for a few abandoned shafts and tunnels.

We left Basiran at 1100 hours on 2 April. The temperature was 16° and there was a sharp wind in our faces; now and then it brought rain. We cross the broad bed of the Basiran River; it contains sand and strips of pebbles up to egg-size with saltwort, tamarisk, and saxaul growing in between. The river begins at the

Kuh-Bala; according to the local inhabitants it is dry here but contains a great deal of salty water 4 km below Basiran at the Tepe-Neisar, so that this hill is named after its abundant growth of reeds. From there the river flows by Arabi and Ambar and is said to join the great river we observed to the west of the Kuh-Bakhtu. The fact that the Basiran River describes such an extraordinary circle is connected with the numerous cases of stream capture which we observed in this area. Probably the river formerly flowed to Qal'eh-Seri and then shifted to the northwest.

In a broad valley depression opening in this direction a small stream bed runs almost directly opposite the upper course of the Basiran river. A few sandy erosion gullies dissect the plain slightly. Where they enter the stream bed, the holy place Mazar-Seyid-Murad stands on a small rock spur. To the left and right small hills, probably remnants of the old valley floor, fill the depression, which is bounded in the northwest by the Kuh-Seri (Gold Mountain) and in the southeast by the Kuh-Shokali. To the north lie the villages Aliabad and Khuliabad. We move gradually uphill over small rubble of a dark eruptive with fine insets of granite and hornblende, but further up we come upon limestones, the same which we noted outcropping with steep dip to the west in Chard-Sard (Cold Fountain), which is south of here. The vegetation in the depression consists mostly of artemisia but there are also other plants.

After 8 km we reach the divide: before us a broad valley trends southwest, flanked on the south by the mountain chains of the Chah-Rustam and Kuh-Gul-Djangdjah and on the north by the chains of the Surbusik. We move downstream along the valley,

which appears to have 2 terraces; the rock has not changed. We pass a well and then, near the Kuh-Rustam, come to a spring which is said to dispense water the year round. After 14 km we reach a second spring near which there are kavir formations and growths of tamarisk; the latter now grow in the stream bed. Soon andesites begin to appear. We pass the black tents of a few people from Basiran who have "wandered into spring," and then enter a broad, cauldron-shaped valley filled with a few hills. It is bounded on the northwest by a tableland of the Khumaka Chain and on the west by the Kuh-Bosou. This valley collects the local drainage; the valley depressions of Qal'eh-Seri lead into it radially. The ruin of the small "Gold Castle" is situated on a rock spur; a still smaller one stands on the other side of the valley. Both were undoubtedly refuge forts for the miners. Below the first one are a few mud huts, an irrigation ditch and a few fields. Further up where a well has been sunk 25 m deep, there are 5 mud huts inhabited by a number of poverty-striken people. They have 60 sheep and an ass, but no poultry or fields or even a sheep dog. We pitch Camp 55 here.

The people suffer from eye diseases and skin eruptions but are otherwise quite healthy despite their poor circumstances. At the present time they are busily engaged in making hard cheese and sour butter from the milk, which is abundant at this time of year, and in shearing the sheep and spinning the wool. The loss of a sheep amounts to a catastrophe here. They cannot afford meat and only the cheaper millet; they obtain the latter in barter.

Our first trip leads to the Gudar-i-Qal'eh-Sangi (Pass of the Rock Castle) which lies to the southwest between Gundja-Dah-Shah

and Bosou. After pacing off a plane table basis almost 2 km long we set out along a stream bed toward the divide. Another valley depression opens up here, running in the same direction; it is apparently a continuation of the one we traveled, but in consequence of stream capture it now swings to the northeast and joins the valley of the compound river which runs northwest from Qal'eh-Seri. Higher up we come upon heavily iron-bearing conglomerates and breccia. Fault traces run through the stream bed here. We find an ore vein in basalt (Rock Sample XCV) with epidotic rock and false lead (Rock Sample XCVI); it shows clear traces of the former mining. The fault traces and ore veins strike 50-60°. Apparently the "Rock Castle," the ruin of a small fort, was designed to protect the Qal'eh-Seri area from the southwest, for the view from the pass is amazing.

The mountains fall away abruptly to the broad plain of the Lut, which is towered over by inselbergs. We take sightings on the Kuh-Bakhtu (119°) and the Chel-Tshila (135°). Not far away is a low chain of sandstones dipping slightly to the north; they are undoubtedly younger transgressive sediments since we know from our earlier observations that the peneplain here consists of old residual fold mountains. The abrupt drop from the Qal'eh-Seri Mountains to the plain undoubtedly represents a fault. The mountains have been subjected to intensive headward erosion in steep-sided V-valleys so that the pass has been pushed back.

On 4 April we circled the Sih-Ching and the Gul-i-Sous-Madena. To the southeast are the peaks of the Bishe Mountains, the Kuh-Gemish (222°), the Siah-Kuh (173°); over all towers the landmark of the Kuh-i-Shah (226°). We cross a broad gravelly

plain hemmed by a bench, and near the steep slopes of the Kuh-Maden-Rogani (Mountain of the Rich Ores) come upon ore veins, almost vertical and striking 50, 90, and 110°. In the shafts, which are half ruined, we find copper veins up to 5 cm thick and beautiful quartz crystals. Although we found sinks and ruined shafts and tunnels here as evidence of the former mining activities, we found nothing so grandiose as the installations described by Khanikoff. The barren rock consists of effusives. The saddle between the Kala-i-Bor and the Maden-Rogani affords us the same amazing view of the Lut. Numerous joints, veins, and scarp zones with breccia and striations provide geological evidence of the block faulting which constitutes the boundary of the Lut -- a fact apparent from the morphology, in any case. Steep-sided V-valleys cut even more sharply here into the face of the mountains. In the retreat of the saddle the peaks have become disassociated to such an extent that a jagged watershed has come into being. We take another sighting on the Kuh-Bakhtu (103°). An inselberg called Bujika is situated in front of the abrupt slope, possibly the edge of an en echelon fault. Traces of abandoned mines are also to be found on the slopes of the Kala-i-Bor. In the ore veins which are almost vertical and strike 70°, we recognize malachite, a vein of lead glance 50 cm thick, and iron-cemented mica. Nearby is a second vein striking 50°. On the way back we cross a small saddle between the Gul-i-Sous-Madena and the Kala-i-Bor; it affords a view of a valley depression with a stream bed leading over a distance of 5 km to our camp site. The stream has a gravel terrace 5 m thick. Numerous prospecting trenches follow the ore veins, which strike 60 or 80°. The rock is for the most part andesite.

On 5 April we hiked across the slope of the Kuh-Pudnei to the Kuh-Bosou. There are only a few traces of the old mining activity here. From the saddle we look out westward over the broad basin which collects the run-off of Qal'eh-Seri. As we pointed out in the notes from the 3 April trip, the stream from the Gudar-i-Qal'eh-Sangi has been tapped and led into this basin at a right angle; here at the saddle it exhibits typical rejuvenation. One can still see how the capture took place on the level of the old valley floor and how the sharp erosion into a V-valley was determined by the greater size of the catchment area resulting from this capture. The disturbance in the drainage pattern probably resulted from the subsidence of the basin; later we shall come upon additional evidence of this. The basin itself is bounded in the northeast by the horizontal tableland of the Homorka Chain, which appears to be constituted of eruptives; to NNW (21°) the latter are overlain by strata complexes dipping to the west. Beyond these peaks we recognize the isolated inselbergs on the stretch between Karimabad and the gateway to the Lut. The Kuh-Bosou, which stands directly before us, is constituted of horizontal limestones with numerous veins and joints.

The next day as we take sightings of the surrounding mountains from the summit of the Gul-i-Safran, we note a considerable deviation of the magnetic needle. It is especially noticeable in the hills at a level of about 50 m and at another level of about 100 m.

On 7 April we break camp and return to Basiran, traveling this time via the parallel valley to the east. We move upstream along a broad valley depression in which a steep-banked stream is

incised. There are 2 clearly recognizable levels, the first 40-50 m high, the second formed by the peaks of hills about 120 m high. The rubble consists of an effusive rock with intensively weathered feldspars; the mountain chains, Riwatshki on the right and Kuh-Gul-Djangdjah on the left, are constituted of the same material. In the west are easterly dipping lava sheets which form sharp ridge forms. Still tracing the 2 levels, we come upon a 5-m thick gravel terrace in which the stream is incised. Soon we reach the divide. It affords a view over a similar valley depression lying between the familiar Chah-i-Rustam and a parallel chain to the east which includes the peaks Panhumi and Sih-Ching. From here it is apparent that the 2 divides and the upper level were formed by the old drainage, which must once have extended from Basiran to Qal'eh-Seri but which was later tapped by the parallel valley to the west. As we move downhill we still see the 2 levels above the gravel. The lower one extends through the gap at the Chah-i-Rustam over into the parallel valley.

We climb to this second divide along a broad valley depression in which the stream has incised a bed about 30 m broad. Till now the vegetation has consisted solely of artemisia and tamarisk, but as we move uphill we come upon luxuriant growths of red and dark-violet dwarf poppies, yellow wolf's milk, and shepherd's purse. Tamarisk grows in the bed itself. Kavir formations and salt efflorescences are common. The valley widens in the upper course. On the right is what might be an old concave slope of the precapture drainage. Beyond the divide are heights on the right up to 100 m united by a common level; above them tower the peaks of the Sih-Ching and the Chah-Sard chains. We cross a shallow depression through which run the source streams of the parallel valley.

The old separation between the latter and this basin exists only in remnants; but only the lower level is still apparent here: the other is to be sought to the right in the heights mentioned above. We cross a low divide which leads over into the drainage system of the Basiran River and then cross a shallow basin drained by 2 broad streams. There are areas of kavir formation here. The isolated inselbergs correspond in their height to the second level. The relatively young gaps and V-forms indicate that the drainage system has not reached base level. We continue across the loam kavir to Basiran.

During the trip (31 March to 7 April) the temperatures varied between a low of 4° C (5 April) and a high of 27° (7 April). The rainfalls were particularly interesting. Throughout the morning of 2 April the southwest wind blew and the sky was overcast, but in the afternoon the sun shone. That evening there was a strong wind from the south which increased during the night to storm proportions and brought with it short but often heavy downpours. On 3 April at 0600 the temperature was 10° and the wind was blowing from the southeast with a force of 4, bringing cirri; the aneroid had risen somewhat. In the morning and afternoon a wind from the west brought a few raindrops; then the sky was swept clear by a wind from the northeast. Rain also fell occasionally on 4 April; the wind was from the west and the temperatures were notably lower (maximum 19°). The wind ceased that night. Before sunrise on 5 April, with no wind and clear sky, we recorded the low of 4°. The south wind soon set in and by noon had attained proportions of great violence at the pass of Qal'eh-Sangi; the temperature was 22° and a few raindrops fell. There were no noteworthy meteorological phenomena during the following days.

This part of the route is characterized by the numerous striking cases of stream capture. They are all to be accounted for by the fact that the erosional processes were rejuvenated by subsidence of the Lut basin and associated basins. To the southwest of Basiran the old drainage ran southwestward across the divide; today the slope has been reversed in places. It is therefore possible that the level which unites the numerous small hills south of Basiran predates the subsidence and capture. The beheaded valley which opens toward Qal'eh-Seri (the one with the spring at the Kuh-Rustam) has 2 valley terraces of recent date beyond the divide; one is tempted to assign them to the 2 established glacial stages but to assign the tectonic disturbances to an earlier period. According to this theory the old valley floor, which can be traced southwest of Basiran, would have originated prior to the time of the "older sedimentary deposits," i.e., during the period immediately preceding the next to the last glacial stage; for the same fault structure we established in the heart of the Lut is indicated here.

Also in line with this theory, the faulting which formed the boundary of the Lut (as noted from the Qal'eh-Sangi Pass and the saddle of the Kuh-Maden-Rogani) would be assigned to the same period. The retreat of the watershed resulting from the sharp V-valley cutting would then be accounted for as the work of the most recent erosion since the next-to-last glacial stage. On the other hand the sandstones which dip slightly north on the edge of the Lut would have to be older. They are apparently the same which we observed elsewhere in slightly disturbed bedding and which probably merge to the Siwalik Hills. The observations and discussions at the end of Route V confirm this theory.

The economic geography of this area on the edge of human habitation is particularly interesting. Agriculture and cattle breeding can be practiced in Basiran because of the nearby high mountains which provide water and summer pasturage. But its size and importance must be attributed also to its central location, which has made it a market town, and to the copper mining. To be sure, the mining boom is a thing of the past; but the fact that some of the houses are constructed of the calcined slag of the copper ore indicates that it is primarily a mining town. Its decline is much like that of other mining towns where the mines have been abandoned, but the situation is particularly difficult here because the people have little other than cattle breeding to fall back on. Basiran proper can irrigate a few fields with its qanat, but even here the people have taken to growing millet, the last resort in agriculture. Millet requires less moisture than wheat and holds up better in case of sheet floods. Wheat tends toward premature ripening and bears less grain. As at Majan, the millet is stored in heavy clay jars as the basic commodity for the entire year. These jars stand in the corners of one and 2-room houses just as they did in Xenophon's day. To be sure, the landed proprietors eat wheat bread here as elsewhere.

In Qal'eh-Seri wheat is not grown at all, and even millet, which constitutes the only cereal eaten there, has to be obtained in barter for wool. The people live in windowless mud huts of stone and loam even more primitive than those of Bishe. Since their roofs are barely higher than the ground, they can only be entered by crawling through the low opening. For food they have only the milk of the sheep and goats and a few beets. Millet is regarded as a delicacy. Weed soup constitutes a large part of

their diet in the spring. During the latter time of year the surplus milk is soured and cooked down to cheese and then dried in small hard balls which are used during the times when there is no milk to make a salty cheese soup called kashk.

There is a well 20-30 m deep, but it provides so little water that artificial irrigation is unthinkable. The loss of a sheep here is almost as grievous as the death of a child, for these "poorest of the poor" have nothing else to lose. They huddle in dumb misery at the foot of the "Gold Castle" in the midst of mountains gleaming with the green-gold of copper veins, and shrug their shoulders in resigned simplicity as they point to the ruins of the primitive smelting ovens among the nearby slag piles. "Here our grandfathers used to smelt copper with bellows and with great quantities of wood, but we no longer know how."

C. From Basiran to Karimabad

On 9 April we break camp and set out toward the north along the path to Birdjand. We cross a broad plain sloping gently toward the west and dotted with a few island hills. The plain is closed off in a funnel shape to the north by the Kuh-Murghi (Bird Mountain), the Gur-Halar, the Kuh-Shurfe, and a number of other heights without names; it is bounded by the mighty wings of the Shah-Kuh. We cross the local qanat, pass a path branching off to the right to Rad-Gaz, and then pass the village Mehmedabad 2 km away on our left. We move gradually uphill across the plain, crossing numerous small erosion channels. There is a rich growth of artemisia here and tamarisk grows up to 40 cm high in the larger stream beds. The rock pavement is remarkably thin and strewn with sand; the small bare heights, which occur only rarely, are made up of rock fragments

hardly as large as an egg. After 4 km we cross a large stream bed running east-west and then climb a small ridge trending in the same direction. From here we have a good view over the plain. It stretches 10 km eastward to the mountains of Kuh-Bala, but in the west it is bounded by mountain chains after only 4 km. At the western end of the plain is the hamlet Aghbari. There are 2 hills before us, one to the left, the other to the right. The western one bears salt efflorescences and a kavir formation. Three kilometers ahead a chain of brownish red hills ranges east-west across the narrowing plain.

The low ridge is covered with clastics which, unlike those of the plain, are about the size of a child's head. We drive down from the ridge and across a sandy stream bed with growths of saxaul and kavir formations. The following erosion channels become deeper and deeper as we move along; some, incised 50 to 100 cm, have reached bedrock of brownish red tuff or dark gray eruptive. The terrain here is rolling, the vegetation of artemisia and saxaul restricted for the most part to the stream beds. Beyond the chain of reddish brown hills, which are constituted of tuffs, we find the plain dissected where it narrows to the "neck of the funnel." We cross the dissected area and arrive at small gorge filled with rubble of a basaltic eruptive. Here, almost 50 m above Basiran, we come upon Sven Hedin's route; on his way from Karimabad to this point he traveled along almost exactly the same stretch we are about to cover. The sighting on "Besirab," as Hedin calls it, is noted in his descriptions from his camp as 156°.

The following plain is also dissected by numerous stream beds running east-west, but unlike the plain we have just crossed

it has extensive bare heights with rocky pavement consisting of pea-size fragments. The large deposits of drift sand, of course, are restricted for the most part to places sheltered from the north wind, but drift sand also appears frequently on the open plain; the vegetation is usually restricted to the stream beds. In the gravelly kavir which comes next are 2 springs Chah-i-Kuru; Sven Hedin pitches his Camp 55 near the more easterly one. From here we can see how various streams from Sar-i-Chah join and run through the gateway to the Lut (which we passed through in Route III) at the Migh-Ambar. The Migh-Ambar (122°) is situated between the Kuh-Belassi (159°) and the Kuh-Arabi (116°).

We cross a largish stream bed with tamarisk; to the left are low, reddish brown hills, probably constituted of tuffs. A hauz stands at the foot. We cross other, shallow streams and come to a loose sand kavir lacking the low artemisia which predominates elsewhere in the plain. After crossing another 2 streams running east-west we find ourselves in the midst of numerous small hills of basalt, some of which have block summits. Narrow erosion channels up to 50 cm deep dissect the plain. The artemisia grows as much as 10 cm high and the tamarisk up to 20 cm. Rock pavement occurs only here and there; frequently a cover of sand or gruss is predominant.

We swing around a hill and cross a rise of the Peterki -- Tshardasi chain of hills which constitutes a short of watershed. Before us lies an area of low hills through which flows the Rud-i-Gaz (Tamarisk River). Its 10-m broad sandy bed, which we now follow, is lined with tamarisk and contains numerous dry water holes. We find hard red tuffs on its banks. Where the river

widens to 70 m and feathers out, tamarisk and salt efflorescences appear in the bed itself, indicating that it has not contained water for a long time. We break a sample of crushed red tuffs from a hill around which the river flows. Near the hill is an extensive bulge in the bed filled with salt. Up till now the river has run at 50° along the direction of strike of the red tuffs but it now swings to the west. Here it runs between low walls of crystalline limestone discolored by iron (Rock Sample XCVIII). In an exposure we observe folded arkose sandstones beneath the limestones. This strata complex is overthrust by sharply folded and overfolded phyllites along an overthrust plane striking 50°. Later mica schists also appear. We are dealing here once again with the basement complex of Alpine structure which we have already encountered frequently -- among other places, not far from here along that part of Route II leading out of Karimabad.

Another kilometer and we reach Hauz-Dehane (Hous-i-Dudehene according to Hedin). To the left rises the Kuh-Tshardasi. Traveling once again NNW we pass a large "Feskanzel" in the river; the latter is less deep here and about 100 m broad with frequent tamarisk shrubs. But we have to leave the river for the sake of our route notes, for 5 km beyond the Hauz-Dehane the compass reflects magnetic disturbances. Khanikoff also reported such disturbances between Basiran and Karimabad, but he does not locate them more precisely. While the Rud-i-Gaz continues along a course of 85° we turn to the right and travel across a smooth plain in the direction of Faizabad. The cover here consists only of sand or a thin pavement with rubble up to the size of a child's head; there are rare occurrences of kavir formations. Toward the Shah-Kuh lies Rad-Gaz, the summer home of the inhabitants of Karimabad,

but we hold toward Kelateh-Semedabad, a settlement consisting of 4 houses, a few trees, and a few fields situated right in the bed of a stream. Further progress is barred by a 500-m broad dune of pure drift sand overgrown with a little dried out saltwort. It extends along a line approximately east-west; the slip-face is toward the north but the south slope also drops abruptly in places. We drive around it through a sandy and muddy river bed and across a plain overgrown with saltwort and broken by a single island hill. We pitch Camp 56 in Faizabad.

The weather throughout the day was characterized by oppressiveness, hazy sky, and a slight south wind; the temperatures varied between 18 and 27° C. As late as 1600 hours we recorded 23°. It was still warm at 1900 hours when a thunderstorm broke with a few but powerful electrical discharges. Only a few drops of rain fell. The temperatures remained high throughout the night, reaching the low of 15° toward morning. When we broke camp for Karimabad at 0830 hours it stood at 18°. The sky was clear and there was no wind.

The stretch from Faizabad to Karimabad consists of a smooth terrain with a few kavir formations and scanty growths of saltwort. We have already reported on Karimabad and the road from there to Birdjand.

This section of the route (presented in detail advisedly) reveals little that is new, although it deals with new material. The great plain of Basiran, which could amost be described as a cauldron, characterizes the first half of the stretch. No doubt the subsidence indicated in the west, i.e., in the Lut, influenced the drainage here too. It tends westward through gaps and must be

antecedent. But we cannot state definitely how the basin was formed. Was it formerly filled in with gravel or sandstones? To be sure, we did not find any residual remnants of such, but they will undoubtedly be found there, for they occur everywhere on the edge of the Lut. It may be that the small pebbles which are characteristic of the deflated surface stem from such remnants.

In the northern part of the basin the streams have cut through to bedrock of tuffs and lavas; but this does not explain the occurrence of the rounded quartz. The "reddish brown chain of hills" (which we observed at 06-04° from the castle at Basiran) is very similar to the sedimentary deposits of Suriha at the foot of the Kuh-i-Shah.

Once again we were struck by the sharp deviation of the magnetic needle. We observed this phenomenon in various places -- at the Kuh-Bakhtu, in Qal'eh-Seri, and now here in the Rud-i-Gaz, southwest of Semedabad. A special investigation of this widespread phenomenon might be of practical interest.

The dune I regard as a southern deposit of the Sar-i-Chah Basin. It conforms to Hedin's law on deposition in eastern Iran (76). This typical zone indicates clearly that the south wind plays a part as well as the north wind in the formation of dunes, a fact I have pointed out elsewhere.

The exposure in the Rud-i-Gaz merits special attention. Unfortunately, the photograph we made of it is no longer available. We are dealing here with the remains of fold mountains, a fact already clearly demonstrated by our observations on the trip out of Karimabad, northwest of this exposure. The 50° line of the

overthrust plane is a direction one encounters frequently in the Qal'eh-Seri area and elsewhere in the Lut. But it should not be forgotten that the present-day structure conforms to this direction only rarely.

We were not able to assemble evidence which would have established indisputably the geologic age here, but the relative age of the various formations can be given.

The so-called basement complex which we encountered repeatedly does not actually constitute the "base," but (as the exposure of Hauz-Dehane indicates) has been thrust under pressure from the southwest over limestones and arkose sandstones. The sedimentary beds of the mountain tract of Bishe, which are younger than the "basement complex" were subjected to 2 periods of folding and a period of faulting which lasted into the most recent time. The cases of river capture represent a complete rearrangement of the river system resulting from the most recent tectonic disturbances.

ROUTE V. FROM BIRDJAND TO ISFANDIYAR AND BACK

(see Sketches 8, 14, 20, 21, and 22)

A. From Birdjand to Khusp

The road from Birdjand to Khusp runs through the great east-west valley depression of the Shur-Rud; it is walled in to the south by the Bakaran Mountains (see Route II) and to the north by various unknown chains. The plain which lies south of Birdjand is well supplied with water. The good brown soil of the many fields provides food for the city itself and for the numerous villages which are located for the most part directly at the foot of the mountains or on the alluvial cones of the mountain streams (144).

The fields accompany us for a distance of 4 km, but the cultivated area, bounded on either side by a weed-overgrown steppe, becomes gradually narrower. Qanats indicate that artificial irrigation is predominant along here, although dry farming is also practiced. After 7 km, having crossed the alluvial plain, which is covered with pebbles up to the size of one's fist, we reach the irrigation ditches, qanats, and fields of the village Amirabad. We reach the village itself after 8 km. It extends almost to the following village, Husainabad. We are particularly struck by the many orchards, the piles of desert weeds collected for heating purposes, and by an ice house in which the ice from the irrigation water is stored. After 11 km, having crossed numerous heat cracks running to the right toward the Shur-Rud, we come to the village Shamsabad; it is partially in ruins but has beautiful orchards. Soon we come to a path branching off to Majan (see Route III), but we continue along the highway through a depression with cultivated fields. These cultivated fields, interrupted here and there by a semidesert, accompany us for another 20 km; we frequently see herds of sheep and goats and even cows. To the right the valley depression is bounded by 3 chains constituted of rust-red sedimentary deposits, limestones, and dark eruptives; unlike those to the south, they have only isolated villages at the foot of their slopes, probably because of a lack of water. The height of the vegetation varies patch-wise, which probably indicates variations in the underlying rock, especially so since we observe this phenomenon frequently.

On his trip from Tun (called Firdaus today) to Birdjand, Bunge (23) reported the existence of a route through this area to the north of the valley depression, apparently more heavily traveled

than today, where routes for automobile highways are now being sought. Ferrier (46) also traveled from Qain to Birdjand along a route west of the Meridional Highway. Bunge reported numerous villages along his stretch, well cultivated fields, and then small, cauldron-shaped valleys with peculiar halophytes; he crossed passes in mountains of marly shale and sandstones. According to the map, the area is characterized by various undrained basins taken over by kavirs and separated from each other by limestone formations. I am not familiar with any more recent reports.

After 17 km we reach the village Tagab with its 500 inhabitants. It has a thriving rug making business, thanks to the initiative of an entrepreneur who owns half of it. The faster and therefore less expensive double knotting method is used, in which 2 transverse threads are worked in with each longitudinal thread. Some of the rugs are shipped from the warehouse in Birdjand to Meshed, but most are shipped directly to the US.

The road now runs in the dry river bed itself which shows here the ruins of an old retaining dike. The qanat water is lead from one bank to the other in U-shaped connecting conduits. The river, which is incised 10-15 m deep in the loam and clay here, frequently has gardens on both sides. The irrigation ditches of these gardens have a winter temperature of 25° C and an overabundance of small fish. We soon reach the village Tosire where fruit trees have been planted on the well developed terraces of the Shur-Rud; here and there strips of land have even been cultivated in the river bed itself. After 28 km we reach the Khusp city.

Khusp is situated at the point where the Shur-Rud enters the basin of the Lut and is the last large, permanent settlement

before the desert. It owes its existence in large part to the relatively great abundance of water in the nearby mountains. In constant danger because of its location on the edge of the desert, the city was protected against the attacks by the Baluchi and other nomad tribes, which were formerly so common, by its location flush on the edge of the 15-m deep river bed and by means of walls, crooked streets, and a roomy refuge castle. According to the inhabitants, snow does not fall every winter and the 4 to 5 month winter rainy season lasts until the Persian New Year, i.e., till the beginning of spring. But according to our observations in the nearby areas, the period of precipitation might well last from December into April. The summers are undeniably hot. The northeast wind apparently prevails during the summer, for the bad-girs on the domed roofs are turned in this direction. The hot season here is extremely unhealthy, malaria and other fevers being common, so that the inhabitants prefer to leave the city if possible during the summer. The population (2,000) consists primarily of farmers, most of whom, unlike those in the villages in the surrounding area, have managed to maintain their independence. A few craftsmen work in the small bazaar, chiefly shoemakers and carpenters. Khusp is renowned for the outstanding quality of its pomegranates and grapes and for the thick syrups made by cooking down these 2 fruits. Dry farming usually fails here and is seldom attempted. In the fields irrigated by the 5 qanats the chief crops are wheat and barley and, in increasing quantity, cotton from American seed. The latter is said to be inferior in yield but outstanding in whiteness. Here, and indeed throughout the whole valley depression, there is a considerable egg production. They sell for a very low price, one rial for 20 eggs. Some income is gained

from the sale of wood from the Kuh-i-Garm-Ab which stands to the west of here. A camel load of faggots sells for one toman in Birdjand. The cultivation of millet, lentils, and beets is declining.

Along the edge of the desert roam the nomadic tribes of the Bahluli, divided into the Ahmad-Huseni, Terheri, and Mahisenali. Their sheep and camel herds fare well during the rainy years but suffer heavy losses in the drier ones. Asafetida is collected from the angusah bushes (Ferula aliacea Boiss) of the Kuh-i-Garm-Ab and used as a drug. Near Khusp lies the holy grave of Sa'er Mollah Mohammed-el-Hussam, said to be 200 years old.

The morphology of the broad Birdjand valley depression, through which the Shur-Rud flows will be discussed later. As for the economic geography, it should be noted that the settlements are located near the main road (during some seasons and in places in the river bed itself) or at the mouths of the tributary valleys. The majority are located on the northward-facing slope which is cooler and has a greater abundance of water. The agricultural areas, which extend a surprisingly great distance westward from Birdjand, include considerable areas of nonirrigated farming. Fruit is grown in large quantities. In animal husbandry we were particularly impressed by the widespread raising of cows. They are a dwarf breed, apparently descended from those of Zabolistan.

The following roads lead out of Khusp:

1. to Sar-i-Chah (Route II);

2. to Naiband via Fidishk (400 inhabitants), Nalinku (one house), Garm-Ab (with warm springs, seasonal camping ground of the nomads), and the spring of Andjira;

3. to Khur, the continuation of our present route.

B. From Khusp to Khur

We continue on our way in the bed of the Shur-Rud, which is almost 100 m broad here and has a cut bank on the right averaging 10 m in height and a slip-off slope on the left. On the right is the village Eshmesh-Kuh with many extensive fields. The warm qanat water running to these fields steams in the 3^{o} noonday temperature. We drive up one of the tributary stream beds, passing reeds and yew and even a meadow, till we reach a level from which we can look out over the scene to the south. This side of the Birdjand River are cotton fields; beyond the river is a plain with small hills drowned in talus. The snow-covered Shah-Kuh (2,600 m) towers above the truncated pyramid of the Kuh-i-Rich (2,480 m). Far to the right on the other side of the Lut basin are the snow-capped mountains of Shah-Dat (up to 3,990 m).

As soon as we have left the depression of the Shur-Rud the relative abundance of water comes to an end. We pass Kelateh-Kasi which consists of only 3 houses, cross a semidesert with isolated desert plants and a mantle of fine rock rubble; it exhibits clod kavir formations here and there. Near the village Gurdjen, which stands on a small hill, we find a few small cotton fields. Leaving the kavir soil behind us, we enter an area of melaphyre hills (Rock Sample XXII) where the vegetation is denser. We are approaching a chain of mountains on the right constituted of steeply dipping

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strata and capped by a degradation level. Here where there are mountains to provide water we find settlements again. Ali-Nesar consists of only one farm with a few trees and cucumber, melon, and wheat fields. The fields are surrounded by mud walls, indicating irrigation by inundation. The village Dastgird, situated on a slope, has 8 houses and 30 inhabitants, all tenant farmers engaged in raising wheat, barley, cotton and fodder beets.

The stretch between Dastgird and Djambu (15 km) runs uphill and down through a hilly area which in the second half of the stretch slopes downward and merges to a waste-mantled plain. The peaks of a few hills buried in the rubble jut out of the plain. Obviously young conglomerates which we had observed earlier in horizontal bedding appear here striking north-south and dipping steeply, evidence of recent orogenic disturbances. Later we come upon andesites and greenish eruptives. From a high point 4 km beyond Dastgird we can see clearly that the peaks of the hills have a uniform level, which then turns down into the rubble-strewn plain. The dry river beds in which the path runs or which it crosses are often incised as much as 10 m deep and contain debris up to the size of one's head; apparently water flows in them at times with great violence. In and near these streams grow fine-branched saxaul and tamarisk, often in tall bushes. Desert plants grow more and more sparsely as one proceeds away from the streams but they are cut everywhere as firewood. Three kilometers to the left, hidden from our sight by inselbergs is the village Djufrud; one km to the right is Kelateh-je-Kuhna, abandoned for lack of water. Djambu itself has a small pond but even here the battle for water is a hard one. The inhabitants, all landless, work as hired labor and are demoralized by opium smoking. The

area is flanked on the right by the Kuh-i-Gurung which is slightly folded and trends generally north-south. To the left, in front of the Kuh-i-Garm-Ab, is another low chain which disintegrates into isolated inselbergs. The Kuh-i-Garm-Ab derives its name from its many hot springs. There are said to be old copper mines there.

The ground along the way to Khur is frequently soft from chemical action but crusted over with a hard rock pavement. Even in the stream beds, which are overgrown with tall tamarisk shrubs there are salt efflorescences as signs of a long period of dryness. The surrounding semidesert is strewn with very fine clastics; the withered plants have almost all been cut. We frequently break through the surface, for under the hard layer of clastics is dust. Thus we reach Khur.

Khur is well fortified by its walls and by the dry bed of the river, which has been made into a moat; it is ringed in the east by brown loam kavir. The city probably once sheltered as many as 1,500 inhabitants, but today there are only a few families and the city is largely destroyed. In the winter the ruins are inhabited by nomad tribes. Most of the inhabitants of Khur have succumbed to the opium habit. Having sold their last possessions to buy the drug, enervated and prematurely old, they have either died or wandered off as beggars. Therefore the nomads, who do not touch the poison, have been able to take over the city.

Although it is situated further north, Khur is undoubtedly warmer than Khusp, for the latter is 100 m higher and located nearer the mountains. There are also greater extremes of temperature in Khur. On 24 and 25 December we recorded evening and early morning temperatures of 0 and -4° respectively. The summers are

said to be extremely hot. Here too, judging by the positions of the badgirs, the northeast wind prevails rather than the north wind.

Only a single palm tree indicates that we are in a "warm country." Unlike Khusp, Khur has no vegetable gardens. The salty fields of the surrounding area bear a little wheat, barley, cotton, and fodder beets. Most of the nearby settlements are only nomad villages: during the winter vegetation period they are inhabited by the wandering tribes Behmedi and Djumali, but in the summer, when the desert plants in the basin of the Lut wither, they are forsaken; for then the nomads go into the mountains with their cattle to live in tents near the watering places. Among those villages which stand empty during the summer are such as Dem and Shalletabad on the slope of the Kuh-i-Gurung. Others, such as Bukhtar, Shurabad and Noudshat (near Khur); and Tadjuk, Sarsangi, and Tahak (near the mountains), are inhabited in part by settled farmers, with the remaining houses being occupied in the winter by nomads. The village Noudjat, where we pitched camp, has almost 60 houses; at the time of our visit (December) they had all been filled by the influx of the tribes. Five qanats, including 2 with salt water, supply the water for the area around Khur; since they supply the drinking water for both men and cattle, there is frequently a shortage of water during the summer in spite of the reduced population.

Thanks to its location with respect to routes, Khur was formerly important as a trade center. The following highways and paths are still in use today:

1. the highway to Gulshan, formerly Tabas, via Duhak (north);

2. the highway to Firdaus, formerly Tun (north);

3. the highway to Khusp (southeast);

4. the path to Naiband via the Kuh-i-Garmab (south and southwest);

5. the path to Naiband via Shandi-Ali-Risa-Khan (southwest);

6. the path to Ab-i-Garm (hot springs) (west);

7. the path to Arababad (west);

8. the path to Zanagun (west), the continuation of our route.

C. From Khur to Zanagun

The path from Khur to Zanagun, almost 70 km long, leads straight across the upper basin of the Lut. The basin is bounded in the east by the East Iranian Mountains and in the west by the mountain chains Kuh-i-Naiband, Kuh-i-Murghum, and Kuh-i-Isfandiyar; to the south the mountains Kuh-i-Garmab and Kuh-i-Ateshan separate it in part from the southern basin. This route remains to be described.

At first we drive across a desert-like steppe covered with small rock rubble and slightly dissected by numerous gravel-free stream beds in the direction of the Shakasta-Chah-Faroh hills; the latter reveal here and there a north-south alignment. A talus-

mantled plain with loose, rocky gruss slopes southward from the hills. The hills are frequently buried in rubble; larger porphyritic boulders (Rock Sample XXIV) indicate the locations of buried hills. We drive downhill and come to 2 stream beds and a gravelly loam kavir of reddish brown and greenish coloration. The hilly area which we now enter is not constituted solely of the "dark eruptive" of Rock Sample XXV, as is apparent from the changing coloration of the weathering debris. The smallish mountains to the left are constituted of dark-violet, pink, and green tuffs dipping 30° to the southwest. After about 20 km the hills trend through a plain sloping gently to the southwest; the erosion channels are extremely shallow. Only where there are buried hills do we find coarser weathering debris.

At the fiftieth kilometer we climb over a low north-south trending ridge and enter into a landscape of small basins. The first is dry, filled with a sand kavir completely free of vegetation. After crossing a second ridge we come to a barren, sandy sink about 500 m broad; it has been taken over by a brown, clayey clod kavir and is divided by a stream bed with a firmer sand bottom. The next ridge has salt efflorescences and loose soil even at the high point. After passing the third kavir basin on our right, barely touching on its edge, we cross a sandy slope and climb to a higher level with rock debris up to the size of one's fist. Once again we touch on the edge of an undrained basin, which is white with salt, and then cross an undrained, completely white salt and sand kavir 700 m broad. On the slope we break a specimen of strongly kaolinized porphyry (Rock Sample XXVI). To the right is still another kavir basin. The next one we cross is a mirey clay kavir 300 m broad. We then climb to a level 20 m higher

cut by 2 stream beds almost 20 m deep; but even here we observe on our left a small undrained salt and sand kavir basin. We drive up a salt-covered slope and through a narrow pass of olivine basalt. From here we drive downhill to the 50-m broad dry bed of the deepest channel of the Rud-i-Gaz and then across salt and sand kavir, salt-covered slopes, and a broad, barren plain with salt efflorescences in various places, and finally reach our goal, Zanagun.

The vegetation in this part of the route warrants special attention. At the beginning the semidesert here was not significantly different from the other stretches. Near the stream beds and in the spots with fine-grained rocky gruss the vegetation is richer. Zygophyllum predominates in the hilly areas. Beyond the twenty-fifth kilometer -- we have descended 150 m in the meantime -- there is a relatively luxuriant vegetation in the sinks and especially in the dry water channels. The zygophyllum grows up to a meter high and so densely that we were sometimes deceived into believing we saw a scanty bush. The lower the elevation, the richer the vegetation. One could almost speak of a meadowland here in the desert, which is what the Persians call it. Of course at this time, during the winter season, it is visited only by camels. Zygophyllum, artemisia, and tamarisk are predominant with saxaul predominant in the kavir soil. At the forty-fifth kilometer, where the vegetation is the most luxuriant, the tamarisk grows over a meter high, the zygophyllum 80 cm high, the artemisia 30 cm high, and the saltwort hand-high. There is also Salsola Aurant jaca Bgc, a thorny spherical plant, gypsophilia, myrtle, oleander, acacia, and Connarus. In the dry stream beds the artemisia bushes grow only a meter apart but in the higher areas they are more scattered. In the areas covered with coarse weathering debris the vegetation

is extremely sparse. Pens, draw wells, and troughs bear witness to the intensive cattle breeding here in the spring when everything is green. There are also grain fields overgrown with weeds which are maintained by the nomads without artificial irrigation.

When we entered the basin topography the vegetation picture changed completely. The ligneous plants disappeared and all the various types of kavir were completely barren of vegetation. Most of the slopes were bare, even where there were no salt efflorescences. The higher spots still bore "tagatk" (I was not able to determine the German or Latin name of this plant). It also grows in the lower spots along side saltwort, especially in the depression of the semidesert beyond the salt river.

Zanagun, with 300 inhabitants, is a fortified village such as one often encounters here on the edge of the robber infested desert. It is surrounded by walls defended by high round towers. The streets which lead to the well-fortified gates are narrow and winding for purposes of better defense. Each house is so constructed that only the stalls and streams are on the ground level. The living quarters in the second and third stories can only be reached by a narrow outside stairway which can be protected from a fortified platform. In the center of the city a small pond near the threshing floor serves as a water reservoir. These defenses were fully necessary, for there are still terrifying memories here of frequent plunder raids made by the nomads, chiefly the Hassani from Yezd, the Baluchi from the southeast, and the raiders from the Shiraz area.

It is climatically significant that the fruits of the 5 date palms that grow here do not ripen, whereas the date groves of Gulshan,

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which is further north but 300 m lower in elevation, usually yield a harvest. It may be, too, that the people of Zanagun chose the wrong species for their climate. The place has a supply of salt-free qanat water from the Isfandiyar Mountains (reeds and willows grow at the qanat outlets). But the supply of water is not great enough to enable them to increase the area of cultivation. After paying the rent (1/5 of the crop for the land and 1/5 for water) there is not enough wheat left over for local consumption, so that they are obliged to buy more at Firdaus. In addition to wheat, barley, corn, fodder beets, and cotton are raised in the walled in fields in the area around the village. According to the inhabitants, the absence of orchards here is a result of the salinity of the soil. Sykes (152), who was the first European to visit Zanagun, reports that on his way south from Duhak he encountered the first date trees here.

Each family owns 10 to 20 sheep, frequently a cow, and sometimes as many as 5 camels. The latter are used to transport wood and charcoal to the bazaars of the nearby cities, chiefly to Birdjand. The village has a primitive water mill. The summers are hot, but, thanks to the cool north winds from the mountains and the rarity of south winds, they are not unhealthy. Fevers are rare.

D. To Isfandiyar

The way to Isfandiyar leads upstream toward the mountains of the same name along a stream bed which is incised 4 m deep just outside the village. At the time of our visit it was dry. At first the alluvial cone is covered with fine gravel; after the ninth kilometer with pebbles the size of one's fist; and after

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11 km by stones the size of one's head. In the beginning there are salt efflorescences here and there and only sparse camel pasturage; after 4 km the vegetation grows taller, though not more densely, and later it becomes more diversified.

Isfandiyar, situated at the beginning of the alluvial cone, is another fortified village with about 200 inhabitants. Instead of an encircling wall the village is ringed by 3-storied buildings, the outer walls of which are broken only by a single fortified gate. From a distance these houses -- which look strange in so small a village -- remind one of the "high houses" of Hadramaut. Since the mountain side of the village is not so easily protected, a small refuge fort has been built as the last line of defense. Here, as at Zanagun, only stalls and storerooms are to be found on the ground level, the upper stories being reserved as living quarters. Many of the houses have been built into the hillside, so that the second floor can be entered directly from the ground level on one side.

We noted the temperature inversion in Zanagun, toward which the cold air sinks, is 2 to 3° cooler than Isfandiyar, which is 150 m higher and better protected. According to the inhabitants snow falls rarely and then in small quantities. Here, where there are no palms, the summers are probably cooler than in Zanagun; nevertheless, fevers are widespread.

Salt-free water is led on in open ditches rather than qanats. Apricots, mountain figs, pomegranates, many white mulberries, and a few grapes are raised in the orchards northwest of the village. Among the field crops we were particularly struck by the amount of corn. The grain is threshed on the numerous threshing floors in

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the village square and ground in 4 water mills near the spring. There are so many sheep ang goats that meat costs only half as much here as at Khur. Lead is mined in a single mine in the mountains. Here where there is spring water we have free peasants, whereas those peasants who must construct qanats, which requires capital, have been driven to dependency. But under these circumstances the amount of available water is limited and therefore the population of Isfandiyar is also limited.

Prominent visitors here are met with "ispend," i.e., fire in torches or shovels. The custom is probably a survival from pre-Mohammedan fire worship.

The Isfandiyar Mountains which rise behind the village are built up of beds striking north-south and dipping sharply to the east. The thickness and succession of the beds can only be given on the basis of the list of rock specimens, since our other descriptions and notes are no longer available.

	Rock	Thickness in m	Specimen No
(l)	porphyry		XXXIV
(k)	an eruptive of a porphyritic sort	200	XXXIII
(j)	dark dike rock	40	XXXII
(i)	bright tuff	1	XXXI
(h)	agglomerate	50	XXX
(g)	dense, argillaceous red sandstone	5	--
(f)	coarse, deep-red conglomerates with a heavy content of crystalline limestone	30- 40	XXIX
(e)	sandstone with calcite veinlets; slightly weathered; forms low angles in the terrain	20	XXVIII

	Rock	Thickness in m	Specimen No
(d)	coarse conglomerates	1	--
(c)	coarse sandstone	1	XXVII
(b)	basal conglomerates chiefly of crystalline limestone	40	--
(a)	gray crystalline limestones	--	--

The lead mine near the village was reported by Sykes (152).

The view from the Kuh-Isfandiyar out over the upper basin of the upper basin of the Lut reveals the following divisions:

1. the alluvial cone of the Kuh-Isfandiyar: progressively saltier as it flattens out, it leads to the channel at the center of the basin;

2. the salt-covered undrained basins in the hilly area;

3. buried hills, out of which rise isolated larger mountains;

4. the marginal mountains in the east.

On the return trip to Birdjand we follow the same route except that we bypass Khusp, driving straight across from Dastgird to Tagab. The route there leads across a peneplain 7 km broad. It is only slightly dissected, covered with sand and to a lesser extent with loam. There are numerous cultivated fields near Tagab and especially near the large village Nosratabad.

E. Comments on Route V

In the profile of the northern Lut the lowest points (filled by the strongly salt water of the river) lie in the extreme west, just in front of the Isfandiyar Mountains with their indistinct

pediment. In this respect the depression is like the one we found further to the south, where the lowest points are also in the west, i.e., in the bed of the Kal-i-Shur or, further south, in the Namakzar. This similarity in structure constitutes additional grounds for considering the Khur -- Isfandiyar depression as part of the Lut. Not until we come to the southern edge of the Lut do we find the low points elsewhere than in the west; there they are concentrated in the southeast, in the Zangi-Ahmad Desert.

The mountains which bound the northern Lut on the east trend in many diverse directions. North of the Birdjand valley depression, parallel to the Bakaran Mountains (Route II), are a number of mountain chains trending east-west; virtually nothing is known about their structure. On the way to Khur we repeatedly observed rows of hills and chains of mountains trending north-south. The steeply dipping beds probably indicate a subsidence of the Lut. The young gravel deposits here have also been disturbed. According to the map, this meridional trend extends far to the north into the vicinity of Qain, where chains of the East Iranian Mountains trend northwest-southeast. The nappe structure of the latter was indicated in Volume I.

The chain of hills 10 km west of Khur also trends northwest-southeast, but otherwise in the northern Lut basin the drainage, and with it the trend, is predominantly meridional. This is especially noticeable on the western edge of the Lut in the mountains of Isfandiyar and Kuh-i-Murghum which rise 3,000 m and more, i.e., almost 2,000 m above the bed of the Rud-i-Gaz. The Kuh-i-Shuturan (Camel Mountain) could be described as a continuation of these meridional chains. Furon (56) visited this mountain at the

Kelmar Pass (ESE of Gulshan, the former Tabas) where he found dolomitic, hard Fusulina limestones bedded over quartzites, possibly (questionable) dating from the Devonian Period. Over these were bedded pinkish gray oolitic limestones which Furon believes may be from the Triassic Period. The overlying strata were constituted of slates and sandstones with coal lenses, Liassic according to Furon. The age of the strata was not established beyond question, but the meridional trend, which is obviously older than the recent folding, was definitely established. On the way from Isfahan to Gulshan, Furon had previously identified sandstones with siliceous cement bedded unconformably on Permian limestones striking north-south. As I pointed out in Volume I, Furon has repeatedly directed our attention to the Hercynian trend in eastern Iran. He believes the occurrences here to be part of a great axis extending from the Urals across the Iranian geosyncline to Madagascar. We were not able to trace it that far, but there is no doubt that a meridional alignment can also be observed further to the west on the edge of the Lut. South of Naiband, near Hauz-i-Khan, Gray (71) found a black limestone which he places in the Rhaetic Period. Further south, in the mountains of Ravar, the red sandstones, the beds of brown, gypseous clay slates, and the fractured limestone (rudistid), all strike from west to east. Tripper (154) reported northwest-southeast axes near Ravar. To the north, also with a northwest-southeast axis, is the anticline of Naiband in massive limestones; according to Douglas (40, 41) its eastern limb is crushed and broken. The northern side of this anticline is a great overfault. Still further north are the mountains we visited on the western edge of the northern Lut; as we have indicated, they have a meridional trend.

The same is true of the fold mountains between Kerman and Shah-Dat. Frequent reference has been made to the meridional trend in the mountains in the eastern part of the Lut. But in the mountains both to the east and to the west of the Lut the most diverse directions of trend occur together with the predominant meridional one. The available data are not sufficient for far-reaching conclusions, but this much is certain: the meridional trend is predominant in eastern Iran, especially so in the most recent orogenic movements. We were able to confirm this in the fold mountains of Zahidan (see Volume I) as well as on the edges of the Lut. To be sure, the east-west trend is also recognizable in recent time as a continuation of an older orientation; but according to our observations it is of much less importance. In our final summary we shall discuss the recentness of the last tectonic disturbances here.

The eastern part of the northern Lut is characterized by several undrained basins on which we are only poorly informed. Apparently they are taken over by kavir, for I was told that they are impassable after a rainfall. The largest and easternmost is called the Daqq-i-Mahmudabad. It was described by Huntington (84) as the Basin of Chahak. He observed there cliffs from lake terraces consisting of clay beds. In places they were sharply folded, but he believes that the intensity of the folding decreases toward the west, i.e., toward the basin of the Lut. To the west of there is an east-west depression which may represent an en echelon fault. It is flanked by 2 basins, to the north by the Hadjiabad-Kavir with the spurs of the Daqq-i-Birk and to the south by the Daqq-i-Kajivan. These basins must have constituted a single lake at one time, for each of the water levels indicated by the terraces is higher than the low divides between them.

Undrained kavir basins are also to be found to the south at the foot of the mountains Ateshan and Garm-Ab, which bound the northern part of the Lut in the south. We were not able to visit them, but the white salt kavir was recognizable from a distance.

The profile in Sketch 20, based on our route notes, represents the relations between the forty-eighth and seventy-third kilometer on the stretch from Khur to Zanagun. It shows that the small kavir basins are sunk in a higher level which is covered in places by pebbles up to the size of one's fist. East of this level, namely, from the fifty-fifth kilometer on, a surface dissected by numerous stream beds rises to the edge of the Lut. The level indicates a type of peneplanation by the Rud-i-Gaz and its tributaries. The small kavir basins we observed are etched 15 to 25 m in the level which is at an elevation of around 940-950 m. Three of them are undrained. Since it is hardly thinkable that they could have been formed diastrophically, it follows that they must have been formed by deflation and that there was not enough precipitation to bring them into the drainage system. We may therefore conclude that the period of deflation which formed these basins was followed by a period in which the precipitation was greater than it is today; for some of these basins do have outlets which must have been formed by overflow. Such would be impossible under the present climatic conditions. We visited these basins after having encountered heavy snowfalls on the edge of the Lut: the shaded areas were still covered with snow, but there was almost no water on the surface.

Why, one may well ask, do these basins and kavir formations occur precisely here? The stretch between Khur and the fifty-fifth

kilometer mark is dissected by numerous stream beds. To be sure, we encountered along this stretch occasional examples of what our guide called "kavir ground," i.e., a hammada or seerir through which the wheels of the car sank very readily because chemical weathering had turned the subsurface rock to dust, sand or loam. But such areas were rare. As we have already mentioned, we found a few fairly large kavir basins on the edges of the Lut, but the first 55 km beyond Khur we found nothing in any sense comparable to these formations.

There is a certain parallelism to this in the distribution of the vegetation. Normally the vegetation becomes constantly sparser and less diverse as one proceeds into the Lut, but on the route from Khur to the Hauz-i-Sultan-Husain almost the reverse is true. For great distances around this hauz grows a vegetation such as we observed at no other place in the Lut and indeed very seldom anywhere in eastern Iran. The numerous pens, watering troughs, and camp sites (abandoned at this time of year, of course) indicate that this pasture land must be much frequented in the spring.

But at the point where the level with the small basins begins the vegetation picture changes completely. Both the sand kavir and the loam clod kavir are completely barren; the level as a whole exhibits at best only sparse halophytes, and even these are eliminated in places by salt efflorescences.

The luxuriant vegetation in the vicinity of the hauz might be accounted for by increased soil moisture. Here at an elevation of 1,000 m the surface moisture does not evaporate as readily as it does in the middle Lut (not to mention the southern Lut, which is around 700 m lower), so that downhill the available water is

increased by percolation -- chiefly during the half-year of winter. We observed a similar phenomenon in the Gaud-i-Neh; there, in sandy soil, to be sure, there is even a "forest" (see Route I).

The sparseness or complete lack of vegetation west of the fifty-fifth kilometer is due primarily to the heavy salt content of the soil. To the east of the fifty-fifth kilometer mark salt solutions rise to the surface only seasonally and in isolated spots; usually, especially in the rainy season, the salt is washed away in the numerous erosion channels and carried below the surface by the abundant percolating water, so that it can do little damage to the roots of the plants. But to the west, salt solutions rise in such quantity that in places there is an intensive kaolinization of the feldspars. (We also reported this phenomenon in Route I.) The presence of gravel remnants suggests that we may be dealing here with an infilled lake. It is likely that these gravel remnants belong to the "older" sediments, deposited here in the northern Lut as in the southern Lut. To a great extent they were removed in the subsequent period of deflation which etched out the basins; the kaolinization resulting from the salinification assisted in this process. The pluvial time caused some of the basins to overflow, thereby creating outlets and bringing them into the drainage system; in the case of others the precipitation was not great enough to accomplish this. The process of denudation was continued in the most recent period of deflation.

Since there are no indications that gravel depositions in the last pluvial time extended to the level where these small kavir basins are located, and that the gravels there stem from that time, the above explanation seems to us to accord best with our observations.

The most interesting aspects of this route are the cultural-geographical features, even though only tentative answers can be given for the questions they raise. And these answers themselves give rise to new questions. As we have indicated elsewhere (144), this route leads through a very ancient area of civilization. This is apparent from the place names, of which that of the Kuh-i-Rich (Route II) appears to be the oldest. The name of this pyramidal mountain, a sacred place, probably goes back to a pre-Aryan root. The same may be true of the name Khabis (166). The relief sculpture, which we could not find, undoubtedly plays a considerable role in the special position of the mountain. The names of the cities Khur and Khusp also point to the earlier history. The name Khur comes from the old root "khur" or "khor" which occurs also in the word Khurasan (Land of the Rising Sun). Tomaschek and Zetterstroem (157 and 166) trace the name Khusp to the Old Persian "huvaspa," i.e., "rich in horses," whereas Markwart (100) interprets it as meaning "rich in meadows." Contrary to Tomaschek, we believe it very likely that the area really was "rich in horses" 3,000 years ago when the Iranians first came, and that there was a river in Sistan called Huwaspa, of which there remains today only a dry bed which bears water occasionally. We shall refer to this again (see below).

Birdjand, central point on the traffic artery along the river of the same name between the 2 marginal mountain ranges, may derive its name from "burdj" (Castle) and "dshang" (forest, grove), especially so since the local inhabitants still pronounce it "Burdshaend." Thus one might interpret the name Birdjand as a "fortress in the forest" on the road between the ancient settlements at the edges of the mountains, i.e., as a settlement for the

protection of traffic. The area was later deforested by climatic changes and unsystematic timbering.

Khusp, which once had an economic basis much different from the present-day one, was at the crossroads of the east-west and north-south traffic lanes and as such must have had a considerable importance. To what extent the city fulfilled its historical mission is not known; future excavations here should shed light on the subject.

As we mentioned in Route II, the name Kuh-Bakhtu (Bactrian Mountain) is also very old. The name of Isfandiyar may go back to an old king's name in the Persian epic cycle, in which case it means "Given by the Holy One" (Ahuramazda) (166); or it may be related to "isfand" (Fire Shovel). The name of the Kuh-Ateshan (Fire Mountain) also goes back to a pre-Islamic cult. Atesh-Kerdan, or "Fire Lighting," (see Route III) may be connected with Zoroastrianism, which survived for a long time in these mountains. Today, to be sure, there is not enough wood in these areas to permit such rites as burnt sacrifices or the keeping of eternal fires.

Thus these interpretations of the names also indicate that eastern Iran had a different vegetation and different climatic conditions at the time of the coming of the Aryans and even at the time of the Arab invasion. When we investigate this problem, the observations made inside the Lut will prove very helpful, for the history of the development of the area is to be found in the sedimentary deposits, that part that still remains.

On the basis of our observations it appears that after the deposition of the "younger" sediments and during the formation of

the kavir layer there was a complete change in the climate. Instead of deposition, deflation predominated inside the Lut. It is altogether possible that the denudational processes were interrupted by periods of deposition, but we found no evidence to this effect. In any case the end result is clear: the "younger" sedimentary deposits were scoured out, leaving only the elongated ridges as remnants in the heart of the Lut. The fact that these ridges rest on a "pedestal" can only be explained by the supposition that the effects of the denudational processes extended beneath the present day water level and that a lake and then a kavir later formed which protected the underlying structure in mummified form while the forms above the level of the lake or kavir, respectively, remained exposed to abrasion and transportation. We could not expect to find "terraces" corresponding to fluctuations in the level of lake or kavir, for the effects of abrasion are always most intensive at the base with which the loose-textured overlying beds aligned themselves to a greater or less extent.

This firm base appears elsewhere in the clod kavir, sometimes indicating through firmness and smoothness the presence of bedrock near the surface, sometimes indicating only the presence of one or 2 isolated residual boulders. In order to gain information on the processes by which the kavir developed out of the desert lake, we made a few excavations beside the "pedestal" in the vicinity of the lowest of the elongated ridges. These will now be discussed in detail.

In the first and second excavations we found beneath the loam polygon kavir a stratum of brown, loose-textured loam soil interspersed with salt crystals overlying a stratum of gray, somewhat sandier loam; each was 12 cm thick. Thereunder lay the hard

salt sandstone which we repeatedly found as a sort of crustal formation. The third excavation revealed beneath a 2 mm salt rind, a 10-20 cm thick bed of salt and loam overlying fine sand. The latter did not show signs of consolidation till we had dug somewhat deeper; apparently, such a fine sand requires other conditions for crustification.

The profiles from the 2 deeper excavations are represented in Sketch 14. It seems quite typical that the hard salt sandstone is missing in Profile I. The thin stratum No 5 seems to indicate that at this depth formation of a hard sandstone with salt crystals would have been possible if, as in Profile II, there were sand available instead of clay. Sandstone does not form from clay; but equally important with the question of the necessary material is the question of depth below the surface. Thus the sand layer (No 4) in Profile I is compacted, but it is not a salt sandstone because it lies too near the surface. This has been pointed out frequently.

As Kaiser has also indicated, the scant precipitation often penetrates only a few centimeters into dry, sandy soil. So it is understandable that a changed permeability, as in the fine sands mentioned above, would also cause a change in the height of the crust horizon. The ground water deprives the sand of its dryness.

But this means that sand was formed into compacted salt sandstones in a recent process, whereas lime and gypsum crusts are generally regarded as having been formed for the most part in earlier times. Some authors maintain that the same is true of salt crusts.

If we compare the 3 shallow excavations and the profiles (I and II) of the deeper excavations with each other (they were all made in within a quadrangle extending about 1,000 m from the first of the elongated ridges), we see that they all have in common the fact that sand occurs in the upper strata. In all cases it is undoubtedly drift sand; uniformly sorted and with typically flat surface, it was apparently flooded by an encroaching wave. In this transgression the distribution of the sand in the drift sand fields was rearranged in part and here and there somewhat stratified. The uniform grain size also indicates that it could not represent the water-borne deposits. The loam deposits are apparently the sediments of local ponds and pools left by the receding water; the sorting bespeaks the precipitation.

A second parallelism is to be seen in the salt horizons I: 9 and II: 6. They are at almost exactly the same height and both lie over clays which merge to the same brown, slightly porous loam (I: 11 and II: 8). The latter, loosened as a result of the high dispersion, appears to be an old loam kavir such as we described above. The 2 salt horizons merge to the clays without a clear junction. Since one clay bed (II: 7) is gray with reddish brown streaks and the other (I: 10) is reddish brown and contains fine sand grains, it is apparent that the sedimentary constituents of the 2, though of different origin, are parallel in time; the salt horizon above and the loam below enclosed both in the same developmental process.

The disparities between the 2 profiles in middle strata (I: 8, 7, 6 and II: 5, 4) can be explained by the assumption of an intervening stage of denudation during which the clays in

Profile II were removed. On the other hand the brown loam is missing in Profile I, also indicating additional denudation. The conclusion is virtually unavoidable that denudation and deposition followed each other in turn, and that the gaps in the profiles were caused by a stage (or several stages?) of denudation. This would explain the fact that there are differences in the 2 profiles in spite of their being so close together -- especially so in view of the sharp junctions between the strata, for a gradual transition is usually characteristic in this type of material both in overlying and underlying beds.

The sands in I: 8 are transgressive fluviatile sands. The glowing red clay in I: 6 could hardly be regarded as anything other than a deposit from terra rossa soil. That it is not a primary deposit is apparent from the fact that it is so very well laminated.

One might attempt to explain the disparities between the 2 profiles by assuming that the sands and clays were transported to the inner Lut by streams (in part in suspension), and that these streams had become laden with diverse materials in passing through the "older" sediments, which are indeed constituted of materials of exceedingly diverse petrographic character. Even so the strongly heterogeneous character of the strata can only be explained by assuming a time interval.

Hedin (76, page 252) also repeatedly found a "rock-hard salt stratum" beneath the surface in the Great Kavir. He interprets the mud layers as representatives of the end of a pluvial period and the "salt strata" as representatives of a climate similar to that of today. Because of the more humid climate in the Great Kavir the arid period there are characterized by crustification rather than deflation.

After these observations toward an interpretation of the profiles we turn to the summary in the following table.

TABULAR SUMMARY OF POSTGLACIAL PROCESSES IN THE INNER LUT:
BASED ON INTERPRETATION OF THE RESULTS OF THE EXCAVATIONS

Recent Development of the Water Supply in the Inner Lut

No	Stratum in Profile Process	The Surface Is Covered By:	The Surface Relative to That of Today	Characteristics of the Period	Inferences on the Climate of the Period
l	polygon formation	salt polygon kavir and clay polygon kavir	±0	continued drying out	arid as today
k	crust formation	sand clod kavir	+80 to 100 cm	drying up of the lake	not quite so arid as today
j	sedimentation	water	+? cm	rebedding of the dunes sand	somewhat damper than today
i	denudation	dunes sand	end: +? cm beginning: -18 cm	drying up of the lake	somewhat more arid than today
h	deposition of red clay	water	end: ? cm beginning: -30 cm	formation of lake	damper and warmer than today
g	denudation	?	?	?	?
f	deposition of loam and clay	water	end: ? cm beginning: -35 cm	formation of lake	damper than today
e	deposition of fluviatile sands	water	end: ? cm beginning: -45 cm	transgression	damper than today
d	formation of salt crusts	clay kavir	-46 cm	kavir formation	arid as today

Recent Development of the Water Supply in the Inner Lut

No	Stratum in Profile Process	The Surface Is Covered By:	The Surface Relative to That of Today	Characteristics of the Period	Inferences on the Climate of the Period
c	sedimentation	water	end: -50 cm	recession of lake	becoming drier
b	sedimentation	water	?	transgression	damper than today
a	denudation	sand and remnants of the "younger" sediments	end: -? cm beginning: +190 cm	violent storms	extremely arid, more so than today

1. After the great deflationary period (a) in which the "younger" sedimentary deposits were removed, a lake must have formed (b). We did not reach the transgressive strata in our excavations. There we can only say of the processes that (as is demonstrated by strata I: 10, 11 and II: 7, 8) depositions took place in a lake (c) which gradually dried up to form a clay kavir (d). The old salt crusts which still remain bear witness to this. It is possible that still another period of deposition intervened between our deepest strata and the basal strata of the transgression, but we have no evidence for this.

2. In the following time the innermost basin of the Lut filled with water again and after deposition of the basal sands (e) clays and loam were also deposited (f). Because of the clear-cut junctions between the strata in I and also because of the absence of strata in II corresponding to the horizons I: 8 and I: 7, we must assume that a period of denudation intervened (g) and that it was followed by a period during which the red clays were deposited (h). Apparently parts of the catchment area which drained into the Lut had a climate in which terra rossa soils could form. But the second suggested explanation of the disparities between the middle groups of strata in the 2 profiles, namely, the assumption of alternating bedding resulting from the heterogeneous nature of the "older" sediments, leads to the necessity (as we pointed out above) of assuming long pauses between the periods of sedimentation, so that in the final analysis the picture remains the same.

3. The lake then dried up again and the deposits described in the above paragraph fell victim in part to deflation. The sand

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fields which formed at this time (i) were not uniformly distributed since they covered a more or less deflated relief, now deposited in the lower places, now in the higher.

4. Once again the basin filled with water and in the process the dunes sand was redistributed and leveled (j). This explains why this sand is not to be found at the surface in the higher parts of the polygon kavir. With the recession of the last of the Lut lakes, loam and clays were deposited in pools and puddles (excavation 1, 2, 3). The sand clod kavir (k) which then developed did not yet exhibit polygons and therefore represents a somewhat damper climate than that of today.

Other observations in addition to these excavations provide clues to movements in the level of the Lut lake. The fact that the edge of the kavir constitutes a sort of scarp (Route III) indicates that the level of the kavir has subsided. This subsidence, which apparently accompanied the drying out, must have taken place before the Namakzar reached the stage of a polygon kavir, for the polygons were not disturbed by the process.

The continuing process of dessication led to a transition from the sand clod kavir (a type still to be found in the moister northern Lut) to polygon kavir, namely, as the contraction of the swampy ground caused polygonal cracks to develop. Sheet floods streaming down the slopes caused the crystallization of the salt slabs and the latter were coated by sand, gruss, and even gravel transported by the storms (l).

Neither I nor Gabriel observed elevated beaches in the Lut. This fact is quite surprising since, as we have already mentioned

(Route III), almost all of the basins of inner Iran are characterized by such terraces. It may be that the terraces in the Lut fell victim to the processes of denudation or it may be that precisely because of the exceedingly frequent fluctuations in the water level no such terraces formed.

As we have already pointed out, the break in profile at the mouth of the Tabasan Valley may indicate the effects of an elevated beach. But if this is the high water level of the Lut lake -- which is problematical -- we cannot place it in time. If it is, then it must have developed during a period when the "younger" sediments were being deposited. For if it had come into being at a later time it would have left sedimentary deposits on the kavir layer, since it would have been 50 m above the present-day water level. But this as much as to say that in the entire catchment area of the Lut no post-Wuerm climatic period has been capable of producing a water level equal to that which the Wuerm could produce.

These periods, which for the reasons stated in Route III must be assigned to late glacial times, or better, to early postglacial times, do not evidence any great pendulum swings; rather they progressed from one to another, in spite of their contrasts, in modest swings such as one might expect for the time span cited.

Before we undertake a synchronization of the data in our table with the general climatic developments, we must call attention to the results of research in nearby areas. Light can be shed on the recent past from 2 different sources: prehistory and the morphological-geological chronogenesis. The former provides the most direct approach to the prehistoric climatic developments. Especially valuable are the recent accomplishments of the Russians;

these were worked up by a whole staff of scholars in neighboring Turan (155, 156).

It was established that the oldest Neolithic civilization in Turan was one of fishers and hunters. This Kelteminar civilization is assigned to the end of the fourth or beginning of the third millennium B.C. Tolstov writes: "To all appearances the climate was in general more arid than it is today; the dry south winds prevailed. Amu Darya and Syr Darya contained significantly less water" (156, page 75). As is well known, Middle Europe was in the middle warm period at this time.

As I have indicated elsewhere (146), it is precisely the south winds which bring the significant precipitation in the area of the Lut Desert, and they occur in connection with the low pressure areas to the north of here which extend eastward. It could be observed repeatedly that depressions in Turan effect a uniform southern current which encompasses all of eastern Iran and the southern part of Turan as well -- to be sure, in the form of dry fall winds in the latter case. Therefore though the Russians have established that dry south winds prevailed in the debouchure area of the Amu Darya and Syr Darya during the Kelteminar civilization, it does not follow that the fringe areas of the Lut Desert had the same aridity. By inference from the present climatic conditions we should rather assume that these south winds blowing over eastern Iran brought a considerable moisture. This is true of course only of the mountainous areas: the inner Lut was touched only by foehns and remained dry. Even the assertion that the Amu Darya and Syr Darya contained less water at that time does not contradict our conclusions, for the water content of these rivers

does not depend on the amount of precipitation in eastern Iran but rather on that in Turan and northern Afghanistan where rain is brought primarily by the west and northwest winds rather than the south wind (98).

The predominance of south winds in the area south of the Aral Sea can probably be explained only by assuming that the track from the Black Sea eastward across the Caspian and Aral (V d1 and perhaps III a) was more common then, whereas today the V d2 (from the Mediterranean toward Iran and Iraq) is more common. The reason for this shift of the tracks toward the north is perhaps to be sought in a general northward shift of the storm lanes. This is to be expected during the middle warm times, just as we would expect a southward shift in the depression tracks during the Ice Age.

According to Tolstov the following time was marked by outstanding climatic changes in Turan. A damper period with prevailing north winds began about the middle of the third millennium. Various grains were cultivated without artificial irrigation, apparently on Kairen. At this time in Europe the continental climate of the late warm period was predominant. About the middle of the second millennium a new period of aridity began in Turan, during which barchans were formed by north winds. But Tolstov does not regard this process as a result of climatic change, but rather of a change in the course of the Amu Darya near its mouth. Between the end of the second and the beginning of the first millennium the Aral Sea rose for a relatively short time. It is not known whether this flooding was the result of climatic or fluviatile changes.

At the beginning of the first millennium we have the "Amirabad Culture" with agriculture on Kairen involving the use of irrigation. Artificial irrigation did not become an elaborately developed system until the archaic period of Khoresm between the eighth and fourth centuries B.C. The system achieved its highest perfection during the golden age of Khoresm, i.e., from the fourth to the first century B.C. The state declined between the fourth and sixth centuries A.D. and was finally destroyed in the Mongol holocaust.

To summarize the findings of Tolstov's group, about 3,000 B.C. Turan was drier under the predominating influence of the south wind; about 2,500 B.C. damper under the influence of prevailing north winds; about 1,500 B.C. drier again; and about 1,000 B.C. damper once again. It is questionable whether the last-named change was really climatically determined. The archaic period of Khoresm, from the eighth to the fourth century B.C., was characterized once again by aridity.

In any case the findings of the Russians in Turan are no more directly applicable to our area than the investigations of the fluctuations in the level of the Caspian Sea made by Brueckner (25), Gerasimov (67), and Grahmann (70). On the basis of the present knowledge of the Ice Age we must assume that during that time the tendency of the western low pressure areas to move east was greater than it is today and lasted longer into the seasons. But our area is also under the influence of offshoots of the Indian monsoon and of depressions which, when the monsoon turns, move northwest out of the Arabian Sea, causing rare but highly destructive cloudbursts (143). The fact of a damper climate in

India during the Ice Age is indisputably established; of the various works which deal with the early history there (37, 38, 82, 112, 121) not one leaves in doubt that the present-day arid regions of India and Baluchistan had a damper climate then. Therefore the moisture brought by the monsoons must have had its effects in our area too; of course in the innermost Lut these effects were largely indirect, consisting of an increase in the quantity of the water which streams down from the mountains and of a decrease in evaporation. The Indian monsoon, or perhaps its dry "reverse front," must have shifted direction from time to time, for otherwise it would be unthinkable that a tropical forest should have developed along the lower Indus during the third millennium.

A. Stein, with his great experience here and in other arid regions, also indicates a dry period in early historical time. Although in Qala-i-Sardag artificial irrigation is not possible from the Bampur River, there are indications of agriculture in Baluchistan which under present-day conditions could not possibly have been nonirrigated. It is possible in the Bampur region to trace the retreat of agriculture upstream, accompanying the drying up. Can one possibly imagine that in these thinly populated areas so much water was drawn from the upper course of the river as to make agriculture impossible further downstream? Stein points out that in the chalcolithic period in Iran (fourth millennium) qanats were unknown; they were first developed during the drying up period. He believes that the rivers of Turfan contained more water "in old times" (134). Stein's findings in Iranian Baluchistan are of great significance to us, for they are directly applicable to our area.

Girshman (68), the meritorious discoverer of the prehistoric culture at the Tepe Sialk near Kashan, also comes to the conclusion that the idea and the technique of qanat construction did not come into being until the area began to dry up. Arne (4) has established that the Tepe Hissar was largely abandoned by the inhabitants about the middle of the second millennium B.C., after having been heavily populated during the Bronze Age. Schmidt (124) attempts to explain this by the occurrence of an epidemic, but this does not explain why another 2,000 years passed before a new population settled there. It would be easier to draw a parallel with nearby Khoresm and assume that this favored area was resettled because of the return of a damp climate and also because the art of irrigation had been developed in the meantime.

The American expedition to Sistan posits climatic changes as late as 1500 B.C. They base this solely on the observations and conclusions of Huntington; the latter assumed damp periods for 300 B.C. and 900 A.D. and proposed the well known thesis that the great migrations of the various peoples in inner Asia must have been connected with climatic fluctuations. Herzfeld (41) probably hit the nail on the head when he said that it is not necessary to posit a "pulse of Asia" in order to explain small changes in archaeological material. But Herzfeld is familiar with the great changes and he too relates them to climatic change. I had repeated opportunities to discuss the matter with this expert on early Iranian conditions. He regards the deforestation of the inner Iranian mountains as an especially important factor in the decisive change in the landscape.

According to Herzfeld (79) the method of interment changed between the time of Cyrus and that of Darius from cremation to burial and to exposure. At the same time there was a transition from polytheism to monotheism. With the increasing deforestation of inner Iran, conservation of firewood became a virtue. Today it is unthinkable that cremation could be practiced here. As long as this cult survived there must have been considerably more wood available than there is now.

As Christensen (29) has pointed out, the geographical limits of the oldest parts of the Avesta are within eastern Iran. Markwart (100) identifies 5 rivers which, according to these parts of the Avesta, emptied into the Kasasoja (Hamun) Lake, including the Huwaspa (present-day Khuspas-Rud). This name, which stems from "Huwasha," a word frequently found in geographical names here, means "good pasture" -- this in an area which today is a complete wasteland. Of these rivers (aside from the Helmand), only the Farrah-Rud and the Harrut-Rud still flow regularly as far as the Hamun Lake. Two others flow that far now and then. The Sandin, which flows through a desert and is usually dry, never flows that far any more. According to a report by Strabo (this was also pointed out by Markwart), the Debas River, on which Balkh is situated, once extended as far as the Oxus. To be sure, the demands made on this river for irrigation have become so great that we cannot be certain that this, rather than a change in climate, was not the decisive factor in the shortening of its course.

The excavations made by Coon (33, 34) in Iran are undoubtedly of the highest importance for anthropology and for the prehistory of the area, but so far as I know they have never been interpreted by a geologist. On the other hand, the excavations at Qalat Jarmo

near Kirkuk, and those at Jericho on the Jordan have been analyzed geologically by Weight (162) and Zeuner (167) and found to indicate that denudation and sedimentation alternated with each other. Caton-Thompson (27) found the same to be true in Egypt, just as we did in the Lut Desert. Particularly important, it seems to us, is the observation that the postglacial arid period was followed by a damper period (end of the second, beginning of the first millennium B.C.) which then passed over into the present climate.

Pittioni (114) believes it highly probable that the Syrian Desert was inhabited at the time of the early pottery making age (6000-5000 B.C.). He refers to Mallowan's conclusion (99) that the number of prehistoric settlements there is about 5 times the number known to have existed in historical time. About 2500 B.C. a reduction in the amount of precipitation forced a withdrawal from these settlements. Pittioni's position is well supported by Huntington (88) and Rohrbach (120); they point to the countless ruins east of Aleppo and remark that the density of population there (in what is today a semidesert) must have been almost as great as in one of our modern European farming areas.

The postglacial conditions in Egypt were recently critically evaluated. It was concluded that in the period from 8000 to 4000 B.C. there was a greater precipitation than today. But the arid period which followed did not have the effect of an immediate drying out, for the wind removed the humus only gradually and the ground water table did not sink so rapidly; therefore the effects of this climatic change did not find expression in the landscape until a few centuries later. Murray is also of the opinion that the precipitation from the Mediterranean extended further south in

the years between 500 B.C. and 500 A.D. This conclusion, which had already been expressed by Huntington (88), moved Stein to conclude that Palestine must have had about 750 mm of rainfall annually in biblical times, i.e., about 1/3 more than today. Up to the edge of the desert in Palestine there are as many as 2,000 ruins. In the extremely arid Karga, to be sure, Caton-Thompson and Gardener (27) found only deposits dating from the damp Riss and Wuerm glacial stages, such as we also found in the Lut.

It is an accepted fact that the Sahara, which was formerly inhabited, must have undergone climatic change. It is emphasized in the literature that this desert has become constantly drier since the pluvial times and that this is to be attributed as much to decreasing precipitation as to increasing evaporation.

If, with Braidwood (19), we summarize the conclusions of a number of authors (a complete listing of which would not change the basic interpretation of the facts), we see that the archaeologists have also arrived at the conclusion that the end of the Pleistocene marks the end of the period of damp climate. The following periods were marked by climatic fluctuations of less importance which made themselves felt primarily, to use Pittioni's expression (114), at the "neuralgic points," i.e., in the fringe areas between the desert and the inhabited regions. These physical changes had great effects on life however, for even slight fluctuations in precipitation can destroy the basis of life throughout the most diverse biological branches. Braidwood believes the climate was damper in 6000 B.C., which is to be attributed both to atmospheric conditions and the forests which still existed at that time. He assigns the beginnings of agriculture in the area between

the Nile and the Helmand to the time around 6000 B.C. The movements of the inhabitants from the piedmont, where nonirrigated farming could be practiced, to the lowlands, book place in Ubaid timed. It may have been the result of the introduction of artificial irrigation or of a climatic change; Braidwood regards the former as the more probable cause.

The opinions of the specialists in archaeology and prehistory cannot be readily reduced to a common denominator. They agree almost unanimously that climatic change or changes took place in the last millennia during which human civilization developed in the Near East, but there are many diverse opinions as to just when the change or changes took place.

Are not these diverse opinions on the climate of the prehistoric Near East the result of the fact that the climate did not change throughout the area as a whole, but rather within the individual geographic divisions? We have already shown that, whereas the increase in the prevalence of south winds in Turan resulted in a decrease in precipitation there, the increase in south winds resulted in southeastern Iran in an increase in precipitation. The slightest shift in the storm tracks produces not only a general change in precipitation, but also a basic climatic change and (in the southeast) a change in the extent of the monsoon belt, a change in the radius of influence of the tropical depressions from the Indian Ocean, a shift in the thermal depth and so forth.

The physiographical observations are important. Hedin devotes an entire chapter of his book Zu Land nach Indien /To the Land Toward India/ to the postglacial climate changes in Iran.

He emphasizes that precipitation decreased in postglacial times and that as a result the kavir lake disappeared. He disputes Huntington's thesis of a climatic change in historical times, pointing out that "it would require nothing more than an ebb in a Bruckner period to cause a canal used to irrigate the fields of a village to reach that village no longer," and that the village is then "abandoned and a new one established further uphill" (page 246). But it appears that the opinions of these 2 authors are not so completely different. It may be that Huntington goes farther than Hedin, but both agree that the climate has fluctuated in historical times. Such fluctuation makes itself strongly felt at the "neuralgic points" on the edge of the habitation, for here a decline in humidity of only a few percentage points can make broad areas uninhabitable.

Among his important observations in Baluchistan, Vredenburg (159) mentions numerous "dams of the unbelievers," structures built to a considerable height above the course of the river to enclose terraced fields; this is in an area which today is waste and where irrigation would never have been possible. Gabriel (63) discovered similar installations in Sarhad. Vredenburg concludes that there must have been more abundant precipitation there in pre-Mohammedan times. Since he also noted that the walls of the Mohammedan graveyards are constructed with uniform layers of stone in the same manner as these dams, he believes it possible that the area was still under cultivation in early Mohammedan times. None of the Baluchi of today are capable of such construction. But there is no basis whatsoever to the idea that these dams should be assigned to chalcolithic times (14).

Tipper (154) is not entirely correct in assuming that the numerous abandoned qanats constitute in themselves proof of a drying up, for many qanats were caved in by earthquakes; often in such cases it proves less expensive to build a new qanat than to go to the trouble of repairing the old one. Moreover it is frequently necessary to abandon qanats when they have exhausted the ground water and percolating water, since in many cases deepening is not possible.

Blanford (17) also held the opinion that the population of Persia had been much greater 2,000 years earlier because of more abundant precipitation.

Particularly valuable is Huntington's pointing out that the turning point in the development of the topography was apparently reached when the vegetation which had protected the slopes disappeared; from this time on, the debris-laden rivers were (with a few exceptions) no longer capable of vertical erosion, and the valley floors were denuded. At the same time the gradual deterioration of the slopes began, so that agriculture gave way to sheep ang goat raising; the latter for their part also contributed to the devastation of the slopes.

After these pronouncements by researchers in the most diverse fields, most of whom were able to form their opinions on the basis of extensive personal observations, it is surprising to come across the opposite point of view, which even goes so far as to speak of a "reckless . . . use by archaeologists and other researchers of the drying up thesis and of the assumption of climatic changes" (14, page 5). Bobek states that after the period of "lake loess" depositions there was a period of exceptionally strong

deflation followed in recent times by a somewhat damper period which has lasted to the present day. He continues: "one could hardly go wrong in identifying the first period with the Pleistocene, the second with postglacial arid times, and the third with the somewhat damper present." (14, page 25) The reader who has taken the trouble to follow our exposition will not agree with this opinion; for it is contrary to the obvious facts, which, incidentally, I pointed out years ago (147). We know that it is an error to lump together the extensive and diverse deposits in the inner Lut as lake loess -- with or without quotation marks; further, that it is an error to speak of a single period of strong deflation when there were at least 2 such periods. Moreover it is questionable whether the "last period of especially strong deflation" (which is actually our "more recent deflationary period" which followed the deposition of the "younger sediments") can be equated with the "postglacial warm period" which Bobek places at from about 8000 B.C. to 1000 B.C. He bases his precise dating on a culture stratum found in the lower third of the loessial cover south of Gurgan: "it might belong to the Neolithic or late Bronze Age" (14, page 21). We cannot reconcile ourselves to the idea that such far-reaching conclusions on the climate of inner Iran can be drawn on the basis of a culture stratum from another climatic region. Especially so since Anau, which is situated near the place where the culture stratum was found, must have been settled during this same period and repeatedly abandoned because of aridity (20). Moreover the interpretation of the profiles we took in the Lut runs counter to Bobek's opinion. According to our table there were from 3 to 4 dry periods of obviously short duration in addition to the "younger" deflationary period. If the "more recent deflationary period" were equivalent to Bobek's dry period (between the eighth

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and first millennia B.C. with high points between 7000 and 4000), then all of the later strata in the polygon kavir of the Lut, as well as all subsequent arid and damp periods, would have to be the products of the last 3,000 years. This is not likely. It is not likely that so many and such great climatic fluctuations should be concentrated in these few millennia; interestingly enough, Bobek recognizes such fluctuations after his dry period but none before. Furthermore one can hardly imagine that the diverse red and brown clays and the brown loam could have formed in so short a time. Finally it is not possible that the "younger" sediments could have been deposited during both the last glacial stage and the postglacial period, when all researchers agree that the basic change of the exogenous agents from sedimentation to denudation is possible only through a fundamental transformation such as took place at the end of the Ice Age.

Additional excavations in the Great Kavir and in the Lut should lead to a clear picture of late glacial and postglacial developments in inner Iran. Our base is too narrow to permit definitive theses. Nevertheless, we shall attempt to work up general principles and combinations, with the expectation that when more data are available it will be possible to make the necessary corrections.

1. The deposits in the polygon kavir of the southern Lut indicate that after the "more recent deflation period" the alternation between sedimentation and deflation was accompanied by small climatic fluctuations.

2. For the present we can say of this time only that it was postglacial and that it came after the "more recent" deflation

period. It included at least 6 periods which must have been damper than the present and at least 2 which must have been as arid or more arid than the present.

3. One would be equally justified in replacing the expression "at least" with "surely more than," because the junctions reflect the extremes but not the pendulum movement of the climatic fluctuations -- which we are nevertheless obliged to assume. Between stage "k" (crustification) and "l" (polygon formation) there must have been various intermediate stages which resulted from increase or decrease in precipitation without leaving apparent junctions.

4. The diagram in Sketch 21 is a schematic representation of the developmental processes during this time.

In the sedimentation periods (b, c, e, f, h, j) the water level lay above the present-day kavir (l) and the one immediately preceding (k). In the deflation period the "pedestal" is formed, being as we mentioned above, partially covered with kavir. It proves that since the "more recent" deflation period (a) various other such must have been predominant; for, as the diagram shows, the formation of the "pedestal" would have been possible only if the deflation period (a) was interrupted by sedimentation periods.

5. There is no doubt that the recent development progressed from the stage of the desert lake (with unknown, probably fluctuating, water level) to the final, present-day stage of polygon kavir. This last high water level of the desert lake Namakzar may reflect the last demonstrable dampness maximum at the beginning of the first millennium B.C. After this time the increasing

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aridity (together with the progressive deforestation) wrought its effects ever more strongly, even though there may have been intervening periods of greater dampness. In this epoch we have the drying up of the rivers Sistan and Baluchistan, the abandonment of the cult of cremation, the abandonment of the fields on the mountain slopes, and other effects reported in the literature. We have not included Huntington's marine terraces because their age assignment is disputed. The following should be noted.

(a) Old names of meadows which indicate the former existence of forests are of Persian origin, therefore must have been assigned after the Iranians took over the interior of the country; it follows that there must have been extensive forest tracts at that time. But these migrating Aryans also adopted some already existing names, e.g., Kuh-i-Rich and Khabis (Shah-Dat today). Thus we have something to go by at the end of the second and the beginning of the first millennium B.C. The Mohammedan conquest also provides us with points of departure. Various names stem from the holy fire of the cult of Zoroastrianism and indicate that the forests had been reduced to a few places where they were protected as sacred; the Islamization put an end to these last remaining tracts. This is indicated by the Arab geographers who, according to Schwarz (125), report forests in the mountains of Kerman. Istakhri (125) calls special attention to the forest of Dje-bel-Bariz; but the very fact of his calling attention to it indicates that he was dealing with something of a rarity. Therefore we are obliged to conclude that the mountain forests of eastern Iran had already been largely destroyed by the tenth century when the Arab historians wrote. Even Marco Polo, writing at the end of the third century [sic], speaks in his report on the region

of Tun (Firdaus today) and Qain of an extensive plain called Albero Secco which over an area of 100 miles (excepting one side 10 miles long) was completely overgrown with plane trees. Today throughout all of the East Iranian Mountains, it would be impossible to find a forest of this magnitude. But the very name Albero Secco (dry tree) seems to indicate that the process of withering up was already characteristic of these trees. They were probably destroyed with the gradual disappearance of the ground water.

(b) There is an extensive literature, both pro and con, on the question of climatic change in historical time. We are not in position to hold definitive opinions on this subject, but we should like to make a few observations. In the desert on the road from Sar-i-Chah to Shah-Dat we came upon the ruined cistern Bala-Hauz (Upper Fountain); the caravan guides state that it has never contained water. Their contention that it was built by Shah Abbas does not seem too trustworthy. But one wonders why so costly and ingenious a structure should have been set up here if the builder did not have reason to expect it to be filled with rain water -- an expectation wholly out of the question under present-day conditions of precipitation. Khanikoff (93) is pursuing the same idea when he states that the Birdjand River, the compound river in the eastern part of the middle Lut, is dry when it leaves the inhabited area and has never borne water into the Lut proper within the memory of mankind.

On his way from Shah-Dat to Deh-Salm, Gabriel (62) found near the Puseh Gushkal remnants of baked tiles and numerous shards of fired clay, the necks and handles of containers of a sort which would never have taken on a desert journey. These relics must be

traces of an old settlement, which would be unthinkable in the southern Lut of today.

The road from Deh-Salm to Narmanshir, which was known to the Arabs as the "new," is not traveled today. On the basis of Gabriel's experiences and the information which I picked up in Deh-Salm, we believe it must be impassable at the present time.

According to Tomaschek Schindler-Houtum found a notice to the effect that a main road formerly existed along the western edge of the desert leading from Bam to Ravar via Shah-Dat. Today it is as completely abandoned as the highway along the eastern edge of the East Iranian Mountains, probably the same highway which Alexander followed on his way to Sistan. Hedin's attempts (77) to prove that Alexander on his way through Gedrosien (Southern Baluchistan) found the same climatic conditions as exist today are not convincing. At the same time he cites Holdrich, a genuine expert on southern Baluchistan, who presents a picture of the Arab times there (end of the first millennium A.D.) based wholly on the assumption of abundant precipitation. If then fluctuations in dampness are possible and if these actually had their effects in the Middle Ages, it is hard to see why the same should be denied for other periods; especially so, since the feat proposed by Craterus of marching with Indian elephants across Sistan to Kerman would be no more possible today than would be the elephant transport through the Sahara which existed 2,000 years ago. Nor can one go along with Tomaschek (157) in his contention that the landscape has not changed since the time of the Arab geographers. The ruins of Deh-Salm and the great field of fragments reported there by Mukadassi point to the former existence of a much larger

settlement. I have already pointed out the other differences. The important changes in Sistan were recently evaluated anew by an American expedition (45) and related to climatic changes.

(c) The qanats or keris: these magnificent underground installations for the supply of drinking and, above all, irrigation water constitute clear proof of the drying up. I have indicated this in part elsewhere (140). This underground artificial irrigation system, which is certainly very old, apparently got its start in the practice of leading on surface water from rivers and ponds. Braidwood (14) can only surmise that qanats must have existed as early as 4000-5000 B.C. in Mesopotamia; but it is proven that there was an extensive artificial irrigation system as early as the protoliterate phase (3200-2900 B.C.). In any case artificial irrigation in Mesopotamia is older than writing (per Soden, orally).

According to the legendary accounts of the Persians, Husheng, the second of the mythical ruling race Pesdadier, discovered fire by striking sparks and also invented artificial irrigation. The fact that the legend ascribes the discovery of both fire and irrigation to the second king is indicative of the great age of qanat irrigation. But it is a mistake to believe that the high floods (which, incidentally, are called "sel" in eastern Iran as in Arabia and are greatly feared) could be used for artificial irrigation. Only the most modern technology would be capable of harnessing the great violence of these eastern Iranian floods; frequent notice has been taken of this violence (149). Qanat irrigation on the other hand makes use of ground water. The high technological level reflected in the installation of the shafts and tunnels, the masterful ability to sink the shafts, dig the tunnels, and maintain

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the correct direction without benefit of a compass, amazes every European engineer who has seen them. Those at Kerman and Yezd, for example, exceed 30 km in length and 100 m in depth. Moreover the gradient of the tunnels must be such that the water will flow but (insofar as possible) not erode. The highly developed technique of qanat construction must have been achieved through generations of experience. The process apparently began when the people dug in the stream beds in quest of the disappearing moisture (a practice still to be observed in the region of Kuh-i-Hezar). Later they learned to build tunnels as conduits for the ground water, and still later they connected these conduits with each other. Such a product of experience is not achieved by a people who have just migrated into the desert. Rather the technique must have been developed through generations in the course of the gradual drying up of the land; the accomplishment was necessitated by the battle for survival.

Apparently the qanat is an inner Iranian invention. Qanats were first reported in Persia by Polybius, but 300 years earlier when Cambyses conquered Egypt it became known that both Egyptians and Persians built qanats (27). The technique was probably carried by the Arabs further to the west, where the qanats came to be known under the name "foggaras" or "gallery well." Therefore Smith's idea (130) that the qanats stem from the third century B.C. is erroneous.

Anyone who has seen a qanat will admit that the underground work could not be carried out without iron tools. Therefore the earliest installations could only have been constructed sometime after the middle of the second millennium B.C. But the qanats

could not have originated in a time of increasing dampness, for why should one go to the trouble to dig for water when it can be collected in canals on the surface? On the other hand, it would be sensible to develop such a technique at a time when the water in the streams begins to seep away and one is obliged to dig after it. Therefore the beginnings of qanat construction can be assigned to the time following the end of the damp period in the first millennium B.C. Granted this it is understandable that qanats were known in nearby Khorezm in the middle of the first millennium B.C. but not yet known in faraway Egypt.

Clapp (30) regards qanats as of great importance to archaeology and physiography; Vredenburg (159) and Tipper (154), the other 2 geologists of eastern Iran, see in them evidence for a change in the dampness of the country. In the final analysis, qanats are rivers which, after they dried up, were pursued underground by human ingenuity. This is apparent from their peculiar fauna, in particular the fish. Smith (130) is the latest of several authors who have reported on these fish. How could fish, some of which are even blind, develop in a ground water channel without connections with other water courses? We found that newly constructed qanats like the one at Bishe are free of fish, whereas those leading to old centers of civilization like Neh are swarming with fish.

The above summary, which is based on the testimony of geologists, archaeologists, and historians, as well as on various other observations and inferences, shows then that a period of drying out began in the eastern part of Iran in the first millennium B.C. This period was marked, to be sure, by fluctuations. Apparently

it was not caused solely by a climatic change, but also to a considerable extent by the deforestation of the mountains. There was indisputably a drying up in the last phase of the morphological development of the southern Lut. It is possible that the last high water stand of the Namakzar, which ushered in the final developmental period, can be equated in time with this 3,000-year period; but it is equally possible that the last high level mark came much later.

It would not be difficult to bring the observations summarized in the table on pages 249 and 250 into harmony with the archaeological finds of the nearby areas, but we shall forego this, lest we unwittingly fall into the method of a Procrustes. In any case we hope that our observations will be useful to future excavations, whether these be for morphological or archaeological purposes; for, as our investigations show clearly, the answers to many questions on postglacial times are to be found in the basins of inner Iran. A comprehensive survey utilizing observations made in Sistan, the Great Kavir, and the Lut Desert would probably produce the best results.

After we have succeeded in setting up a table of chronology for the recent geological past (including positive relative age and probable absolute age), we should be able to clarify the problem of the complex of terraces and levels which we have touched on in both volumes of this work.

TABLE OF CHRONOLOGY OF THE LAST EPOCH IN THE LUT DESERT AND ITS FRINGE AREAS

No	Sequence of the Phenomena Observed	Probably Corresponds To:
8	The last damp period changes (with fluctuations) to the present arid type	The last 3 millennia
7	The last damp period	End of the second, beginning of the first millennium B.C. (?)
6	Various alternating, relatively short damp and dry periods	Postglacial and late glacial
5	More recent arid and deflationary period, more arid than today	Postglacial and late glacial
4	"Younger" sediments, more recent damp period	Wuerm
3	Older arid and deflationary period, more arid than today	Riss-Wuerm Interglacial
2	"Older" sediments, older damp period	Riss
1	Last great epirogenesis	Pre-Riss

In the course of these discussions we have repeatedly made reference to the great gravel depositions which are to be seen in eastern Iran. Near Sharifabad we found half-compacted conglomerates disintegrated to elongated ridges in which, frequently with an elevation difference of 100 m, low gravel terraces were embedded (I, page 8). These half-compacted conglomerates are especially common near Birdjand; here they are 80-100 m thick and, toward the east tilted 30° to the north. The Birdjand valley depression is closed in the east by clearly recognizable elevated beaches carved out of sand and these conglomerates (I, page 22 and 24).

As we approach the Hamun in Sistan we encounter numerous elongated ridges of half-compacted conglomerates and sandstones with old strand lines (I, page 33 ff). In Hurmuk (I, page 37) we were particularly struck by the fact that the conglomerates and

sandstones are tilted and that a basaltic effusion is interbedded. Overlying is undisturbed river gravel separated by a terrace. The plain of Mirjawa is also attended by great gravel configurations which drop away in terraces to the depression Mashkel (I, page 63). The observations on gravels made in Route II are summarized at the end of Route II. In addition there are the gravel terraces of the Rud-i-Shandik, those near Qal'eh-Seri noted in Route IV, and finally those in Route V. The question of the division is not simple; but in addition to consistency and habitus, tectonic factors also furnish us with insights into the differentiation of the gravels. According to our chronology, the last important epirogenesis in the Lut Desert -- so far as we could tell we are dealing here solely with block movements -- was in pre-Riss times. But there must certainly have been isolated exceptions to this; this is hardly surprising in an earthquake area such as this where faulting still takes place even today (I, page 64). In a few places on the desert fringe areas the sediments bedded with the depositions of Riss and post-Riss times are disturbed. A striking example are the conglomerates and sands of Birdjand which we mentioned above; in the city itself and on the eastern edge of the basin they lie undisturbed, but where one leaves the place they are tilted in places. Since both occurrences are identical in texture it seems reasonable to assume that they are of the same age. We found similar relationships near Qal'eh-Seri (Route IV) and on the stretch between Dastgird and Djambu (Route V). Aside from these few exceptions I, and Gabriel (58-64) as well, found the numerous and widespread recent depositions undisturbed.

The undisturbed gravel depositions are all embedded in a relief which, aside from the changes effected by the cases of

stream capture, is almost exactly like that of today. The valley depressions may have been deeper at times, but the gravel depositions raised the levels considerably. After rejuvenated downcutting and erosion the terraces were formed.

Thus we arrive at the conclusion that the disturbed gravel depositions, clays, sands, loose sandstones, and conglomerates should be assigned cum grano solis to pre-Riss times; the young craters and the recent effusions belong to the same period, e.g., at the Kuh-Givshad and in Hurmuk. In line with this, the conglomerates with the basaltic interbedding, which were described in Volume I (page 37) as a sort of "young Siwaliks," should be assigned to pre-Riss times. On the other hand, the younger gravel, overlying and undisturbed, which fills the valley south of Hurmuk were laid down in Riss times after the faulting of the Zahidan fold mountains and as a result of the block movements there. In Volume I we noted in many places 2 gravel series of different ages, and -- as at the Kuh-Bakhtu -- 2 alluvial cones of different ages. As we have already suggested, these 2 separate phenomena can probably be related in time to the last 2 glacial stages, which have left such clear-cut junctions in the inner Lut. By analogy with the widespread depositions of the "older" sediments, the greater part of the gravels should be assigned to the Riss. Therefore the strong sheet floods of the Riss were responsible for the great gravel depositions, e.g., those that lie undisturbed over the recent volcanic traps near the graveyard at Khusp.

The last interglacial stage was probably characterized by deflation. Of course judging by present conditions there must have also been a certain amount of erosion by the rivers in the fringe

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areas; in view of the dampness, it may have somewhat surpassed the deflationary periods.

But it seems that these processes of erosion and transportation were more successful at times than at others. Lakes formed in the last glacial stage and left their depressions in the wind-protected places in the deposits of the preceding glacial stage until an outlet was found into the main drainage and the heavy water-bearing rivers created new beds in the valley depressions which had been covered with wind-borne sand and the Riss gravels. By tapping, these rivers reversed the old drainage, as at the Kuh-Bakhtu and at Qal'eh-Seri; they then formed the terraces which we have described as the "younger."

The exposure across from Tagab toward the end of Route II also speaks for our interpretation. The clay shales which form the base, judging by their slight undulations (which were apparently formed in pre-Riss times -- a more precise dating is not possible) must have been subjected to a process of denudation. The overlying sands, gravels, and pebbles which have been half-compacted to reddish brown conglomerates and which in their way resemble the "older" terrace gravels, stem from Riss times. To be sure, the exposure might be a remnant of these gravels.

The half-compacted conglomerates bedded on top exhibited cemented coarse sand, indicating that such must have been sorted out in violent storms here in the Birdjand Valley, probably in the last interglacial stage; such storms may still be effective here at the valley depression. Since, of course, sedimentation also takes place in deflationary periods, it is not permissible to assign all deposits to pluvial times; one must also make the

necessary inferences on the basis of the appearance of the sediments. The gravel of the last glacial stage protected the underlying sediments from the ensuing denudation, but apparently it itself fell victim as an entire chain of hills.

We frequently encountered rock terraces which had obviously developed out of gravel terraces; the gravel had been eroded away in places but still remained in other places. Typical is the gravel terrace near Khusp (Route II); the rock terrace near Ambar (Route III) is another example.

The presence here of gravel terraces was established by Huntington, who, to be sure, claims to have observed 4 to 5. Here, as almost everywhere, the terrace gravels are not always at exactly the same level; but where we are dealing with such great masses of gravel, general consistency is more important than a deviation of a few meters. Huntington in dealing with the terrace configurations of the Herirud would like to recognize 2 distinct terraces where there is a difference in level of only one to 4 m! To be sure, he was hardly able to show that all the 5 terraces were of postglacial origin. But we are able to report that he too was impressed by the relative youth of these terraces.

In addition to gravel terraces we occasionally identified valley terraces, for example, on Route II in the Shuragan Valley and on the stretch between Majan and the Shah-Kuh. The gateway to the Lut also exhibits such. In all cases there were 3. Those in the Shuragan Valley are certainly older than the 2 gravel terraces there; the latter are only faintly expressed and for the most part constitute the valley floor. Eventually they lead into the Birdjand Valley where we noted them near the exposure across from

Tagab. Thus both valley terraces buried in part, to be sure, but undeformed, can be traced into the main trunk valley. Typically, there are no valley terraces in the valley depression west of Birdjand for it represents a graben fault, a fact proven by the step faults identified in Route II. While the Birdjand Valley depression subsided, the remnants of the valley floor at the mouth of the Shuragan Valley remained as steps. The fact that the valley terraces diverge toward the head of the valley justifies the assumption that at the same time as the subsidence of the graben the Bakaran Mountains underwent uplift.

We observed the same phenomenon north of the Shah-Kuh Mountains, although we were not able to adduce the same proofs. It is quite possible that the lowest valley terrace corresponds to the "older" terrace gravels, but we were not able to observe this. Judging by the height, the lowest valley terrace must correspond to the "older" terrace gravels in the area of Majan. As we pointed out in Route III, the same is true of the gateway to the Lut.

We also noted valley terraces in the Qal'eh-Seri area. As we have already indicated (Route V), the old valley floor out of which the valley terraces have been formed stems from pre-Riss times. Here, as in the case of the other valley terraces, it is not possible to arrive at a more precise dating.

Finally a word about the peneplanation. This phenomenon is particularly striking where observations shows that it has taken place over mountains of Alpine structure and over rocks of the most diverse resistance potential.

In Volume I we called attention to the peneplanation near Meshed and the peneplain which caps the mountains near Qain. In particular we studied the 2 areas of peneplanation in Zahidan and in various places identified one or 2 old surfaces where broad views were possible. In many cases, to be sure, as in the fold mountains of Zahidan, the continuity of the peneplanation, had been disrupted by recent faulting. These cases of peneplanation, then can be assigned to the time between the epoch in which we assume the last folding to have taken place, namely the late Tertiary, and the time of the most recent faulting, namely the time preceding the Riss-pluvial. We can determine nothing concrete concerning the time of the second peneplanation. Sometimes, north of the Shah-Kuh (Route II), for example, it appears in the form of a trough or as a level lying 50 m lower bordering the old top surface along the slopes, or as in Route I near Ambar it occurs as an altogether different form. In the latter case both areas of peneplanation have obviously subsided as the result of basining; the upper is apparent only by the uniform summit level of the numerous hills, while the younger and lower (50 m) is indicated by the striking flatness. The question raised in Volume I (page 57) as to whether the old top surface is the result of a long period of erosion or whether it represents the beginning of the formation of the present topography (which began in the Miocene), we should like to answer now in favor of the former; for the land surface is not a primary peneplain, but rather a slightly rolling terrain.

In summary we may state that the 2 substantial gravel terraces can be referred to the last 2 glacial stages. This does not rule out the possibility of more recent gravel terraces:

indeed, one can follow their formation even today right after the great storms.

The valley terraces we observed in various places are for the most part older; but in many cases it seems probable that the lowest one is actually an older, denuded gravel terrace.

Even older than these valley terraces are the 2 old top surfaces. Of course the old surface could not have formed until after the last folding. It shows the effects of block faulting in various places.

The reader who has taken the trouble to follow our exposition will realize how complex the geology and tectonics of this region are. Since even specialists have not been able to say anything definitive about the structure of the East Iranian Mountains, the reader will not blame a geographer for the same failing. We believe it better to confine ourselves to reporting our observations rather than to deal in constructions which must remain problematical as long as the data remain incomplete. In Volume I we pointed out that the East Iranian Mountains constitute a region under extraordinarily great tectonic stress, characterized by nappes, overfaults, and great fractures, and a region of unusual lability, with great effusions, volcanoes, warm springs, and frequent earthquake catastrophes. This impression is further strengthened by the material worked up in this volume. It can be demonstrated that 3 to 4 foldings took place before the most recent block faulting (pre-Riss according to our interpretation) brought about additional significant dislocations.

In contrast to the diversity of the directions of strike of the earlier foldings, the recent tectonic lines are for the most part oriented north-south or east-west. It is interesting to note that the fault lines, which can be traced over great distances, take up the old tectonic directions, but in the process cut across other, relatively younger ones. In consideration of the numerous alignments, this is perfectly natural.

Of course in the process of working up these observations we have formed a working hypothesis. We give it here, with all due reservations, in order to present a concluding picture.

We know that an orogen with northern and southern main chains rose out of the Iranian geosyncline. The pressure was exerted from the southwest, and seems to have been especially strong there where the Arabian plateau raised up the mountains of Oman and forced the Zagros chains to swing into an east-west direction. The old basement complex, which here in the Lut is to be obs rved for the most part in a northwest-southeast alignment, resisted this folding but broke and opened up outlets for the magma; in the process the older orogens and the younger sedimentary deposits were enfolded. The movement may have been stopped in the central mountains of Afghanistan, or perhaps in a "mass" in the area of Sistan; this would explain the virgation of the Bakaran Mountains out of the east-west direction into the meridional, and in particular would explain the fact that at the point where the Lut and Sistan basins come closest together, i.e., in the Kuh-i-Palangan, the meridional direction is predominant.

The fact that the folding in Baluchistan was forced to swing around into an east-west direction resulted in the development of

great stresses here in the intermediate area of eastern Iran; this led to the faulting which has been predominant into recent time and which has given the Lut its peculiar topography.

With this the treatise on the observations I made in eastern Iran comes to a close. The task of geography, to describe and to explain, could not always be completely fulfilled here. The data were not sufficient in many cases to permit definitive conclusions. But since we were dealing with an area which had been reported heretofore but little, and in places not at all, every observation is of some value, even if it was only registered in passing and still cannot be interpreted. Thus we can say that we have remained true to the method used in Volume I, to describe the sections of the routes and to treat each problem as it arises.

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ERRATA -- VOLUME I

Page	For	Read
12	Sauerfluss [mineral river]	Salzfluss [salt river]
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48	Khirtas	Khirtar
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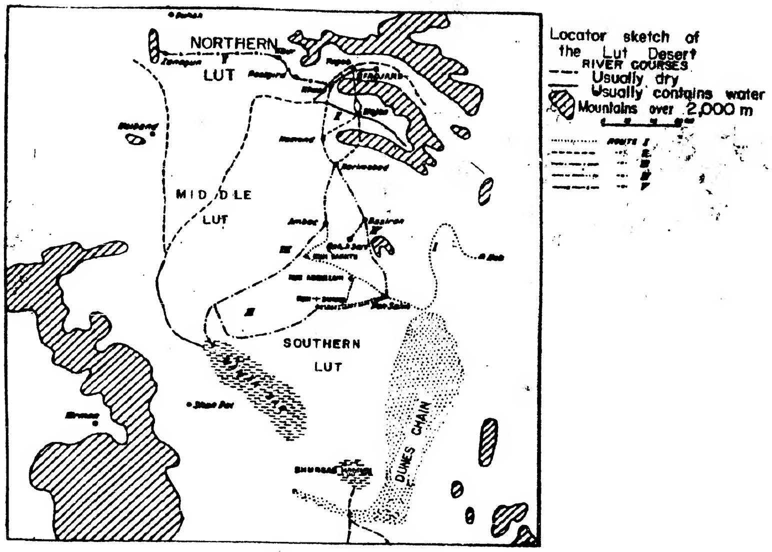
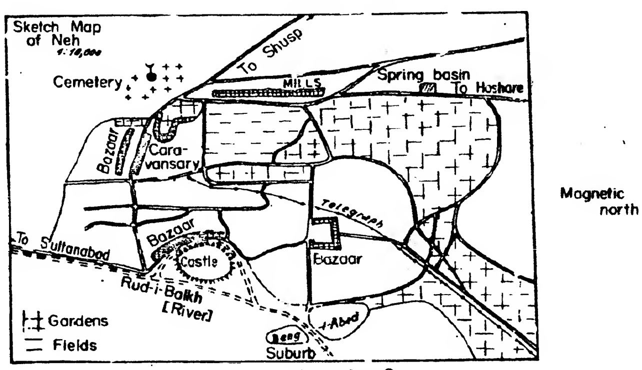
68	Suedwesten /southeast/	Suedosten /southeast/
71	SW-Wind /SW wind/	NW-Wind /NW wind/
88	hippmite --	hippurite



SKETCH 1

Sketch 1 shows the routes which we shall discuss in the following. With the exception of one trip from Karimabad to Birdjand and back, and the trip from Basiran to Qal'eh-Seri and back, all the routes were covered in a normal passenger car (Wanderer, 6 cylinder).



SKETCH 2

The city Neh with about 2,000 inhabitants is an ancient settlement, the last stronghold of the peasantry in the mountains, and the "port city" of the southern desert areas.

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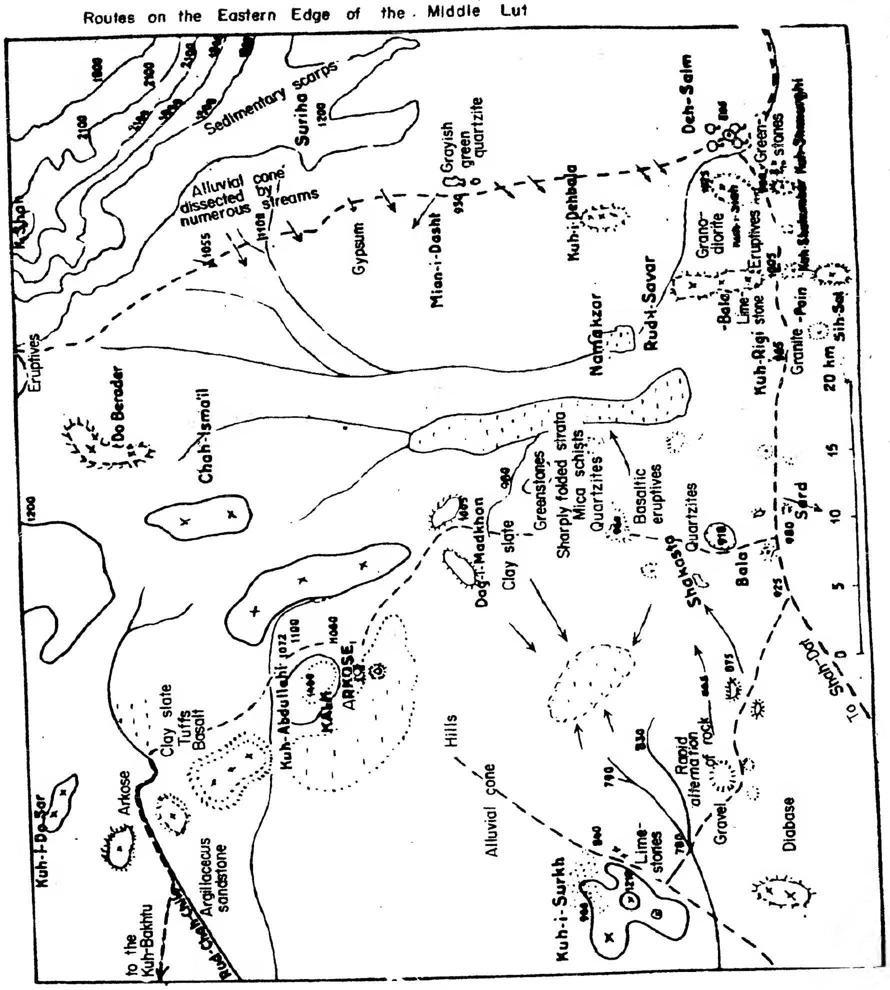
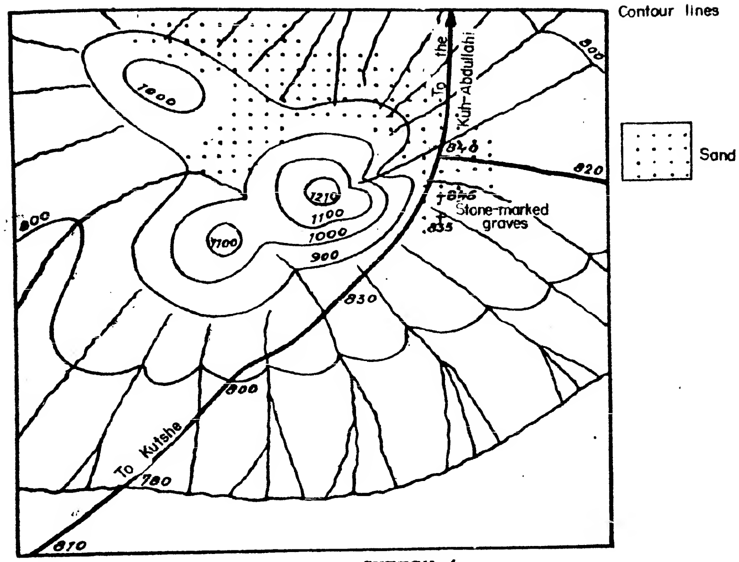
Routes on the Eastern Edge of the Middle Lut

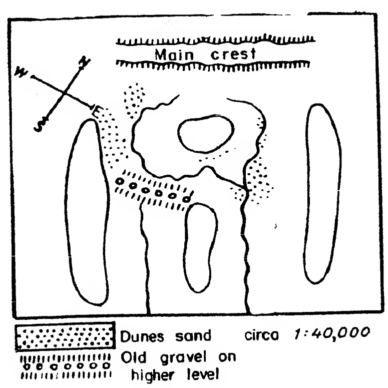


SKETCH 3

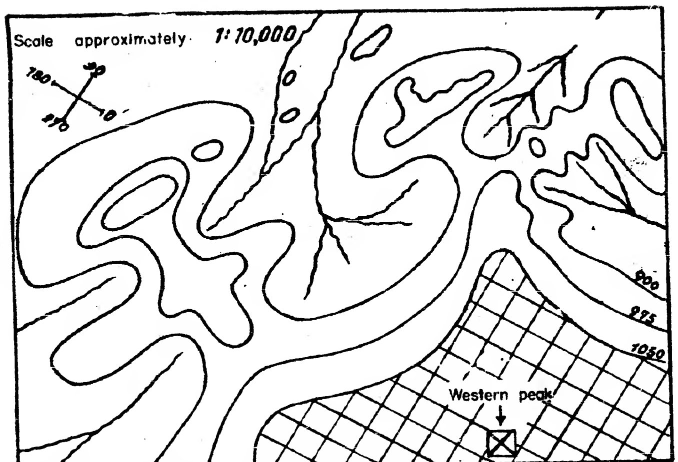


SKETCH 4

Sketch of the Kuh-i-Surkh (scale 1 : 10,000). The Surkh-kuh is a typical inselberg in the eastern part of the middle Lut. It is constituted of dark gray, massively bedded, very hard limestones with karren.

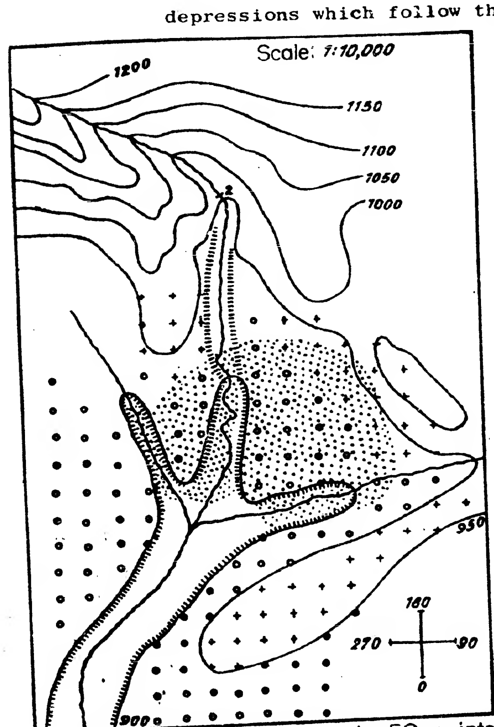


Sketch 5. Stream capture on the south slope of the Kuh-Bakhtu. The stream capture at the Kuh-Bakhtu is indicated morphologically by the old valley course and geologically by the gravels.



Contour lines: interval of approximately 75 m

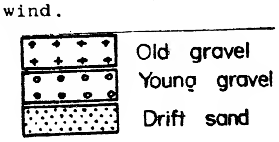
Sketch 6. Disintegration of the southwest corner of the Bakhtu. The disintegration of the Bakhtu is the result of valley depressions which follow the tectonic lines.



Contour lines: approximately 50 m interval

Sketch 7. Streams on the Northwest slope of the Kuh-Bakhtu.

At first the drainage follows the jointing. Then (Point 2) it follows a direct course downward. Here too the river begins to meander as soon as it encounters the drift sand which has been deposited in places protected from the wind.



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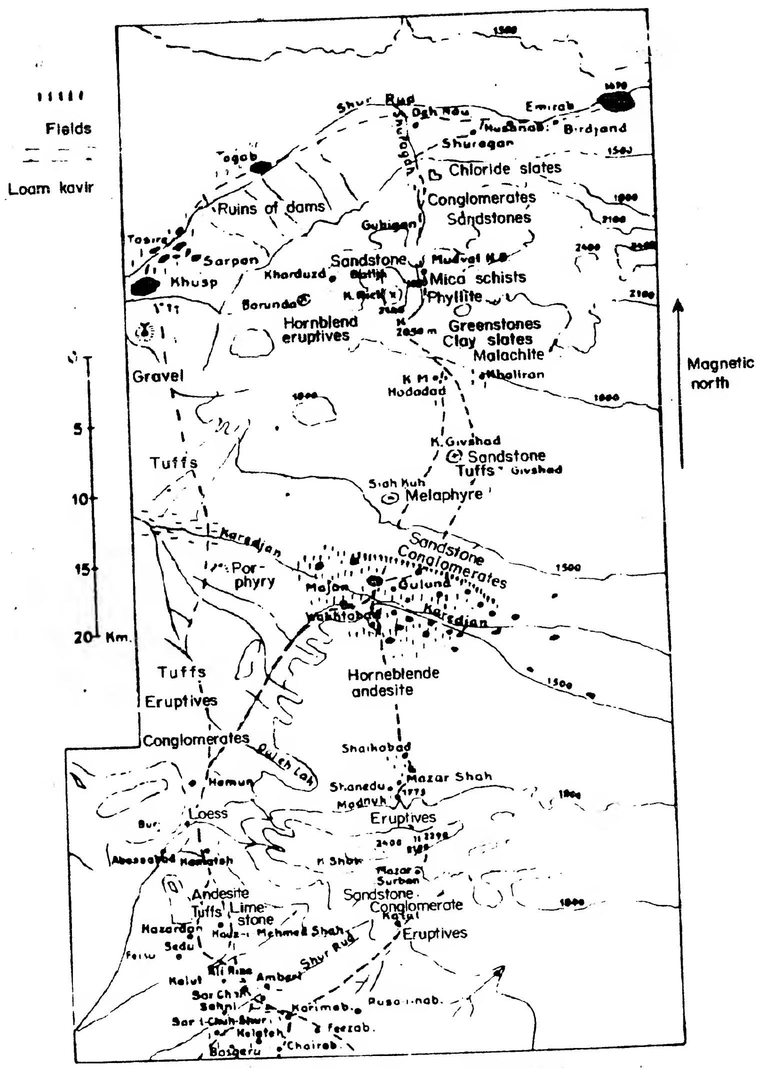
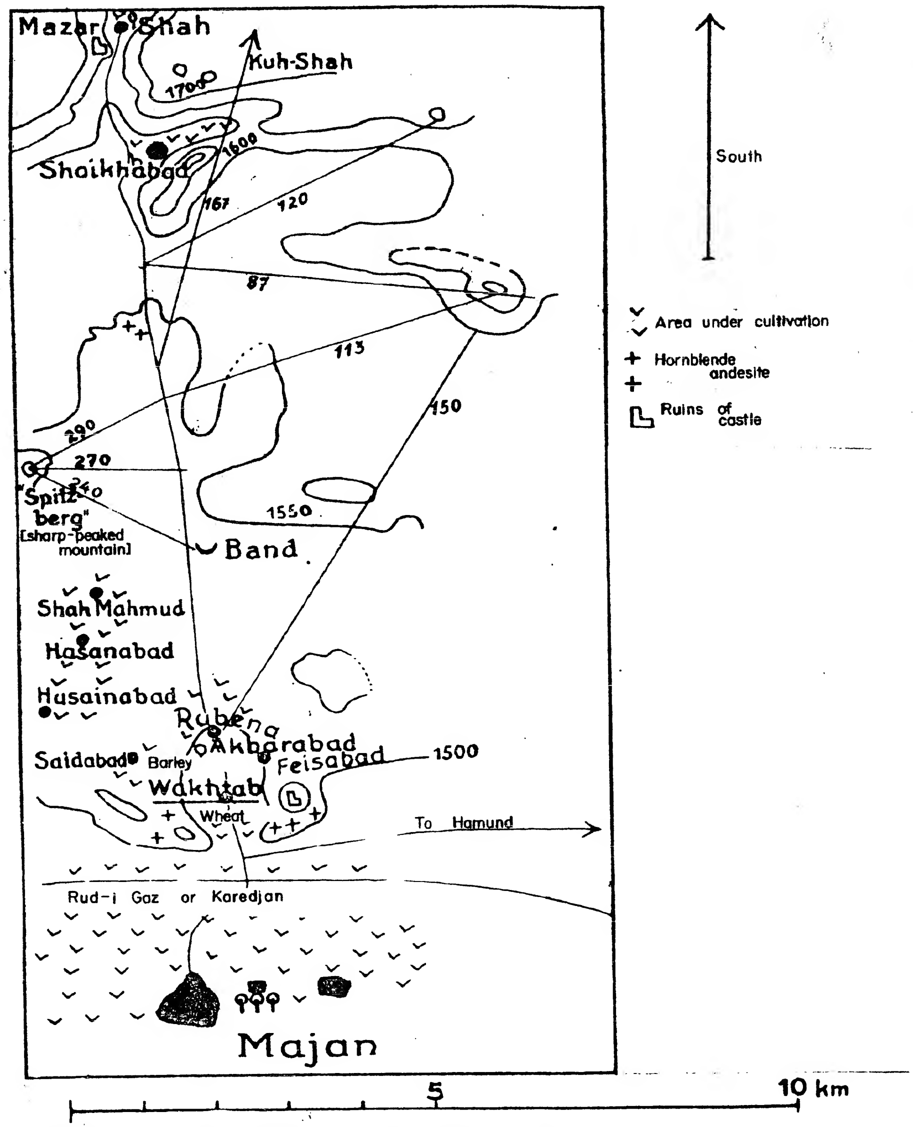
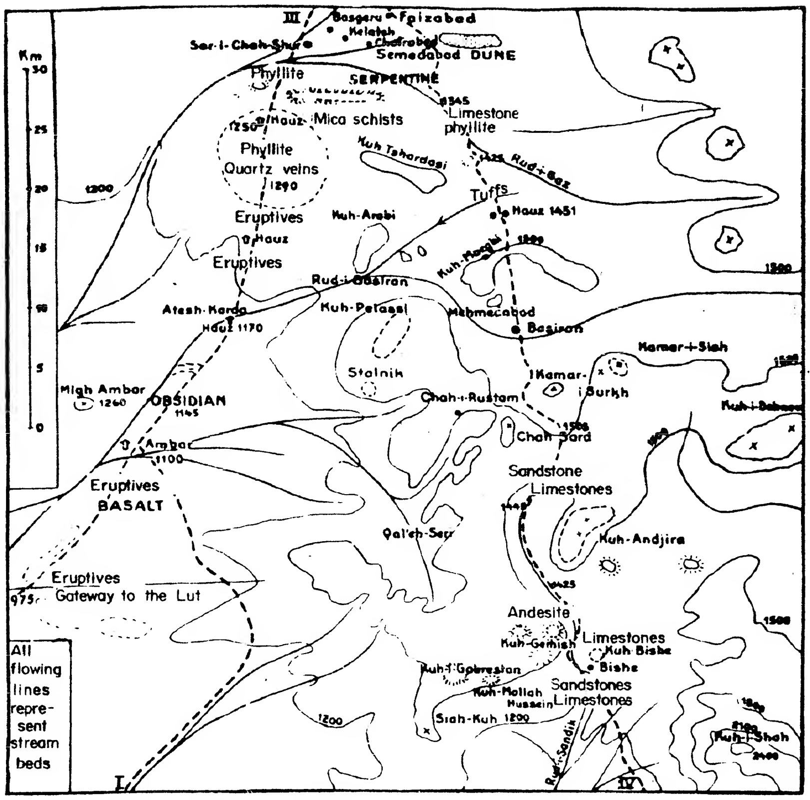


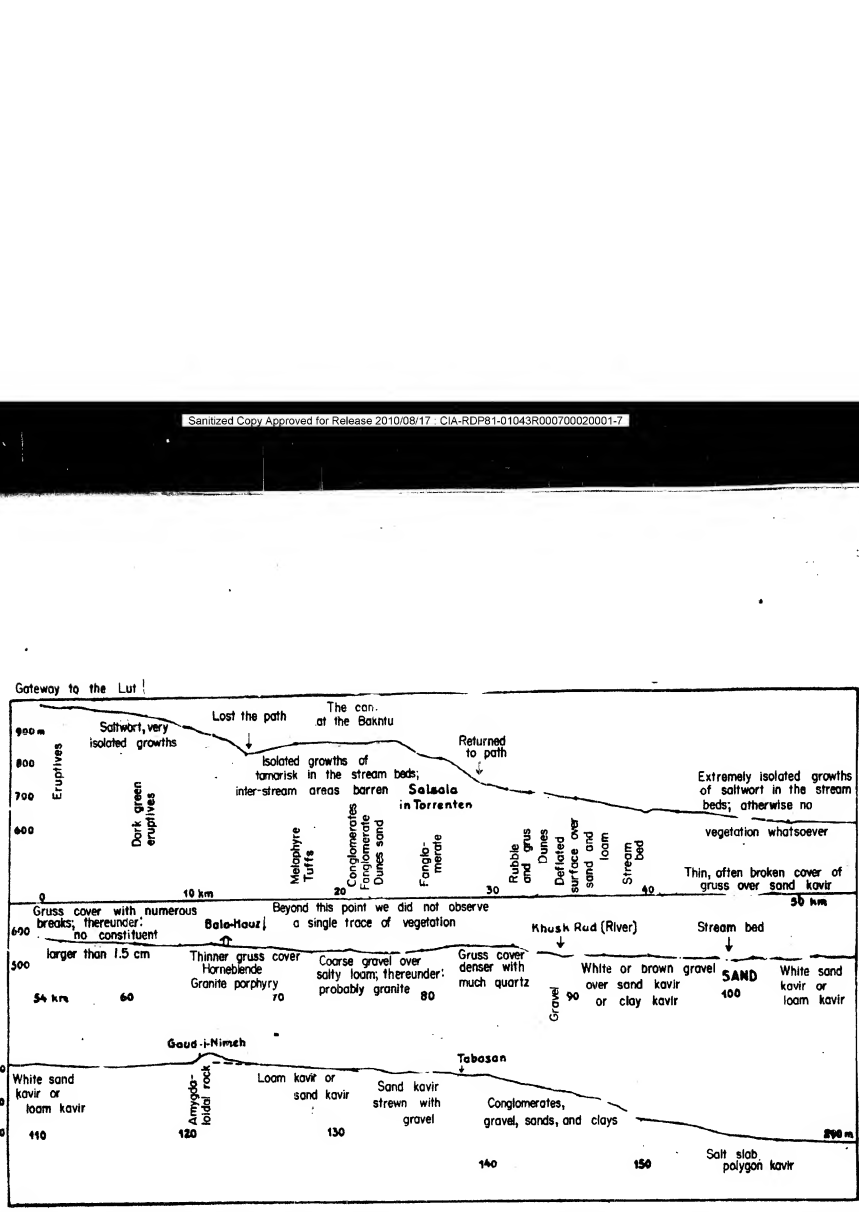
Sketch 8. Route Map, Birdjand -- Karimabad.



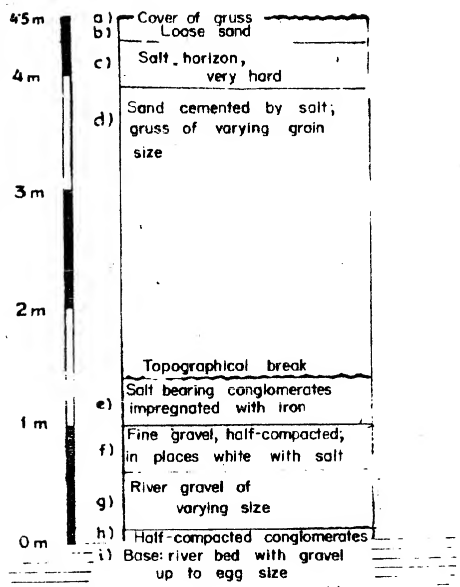
Sketch 9. Route, Majan -- Shaikhabad. The way to the 2,290-m high pass leads through the cultivated land of Majan which has developed a typical oasis economy. Overlooking the area is the ruin of an Assassin castle. Even down on the plain a great deal of nonirrigated farming is practiced. The valley is characterized by 3 valley terraces which diverge toward the head of the valley.



Sketch 10. Route Map, Ambar -- Basiran; for Routes I, III, and IV.

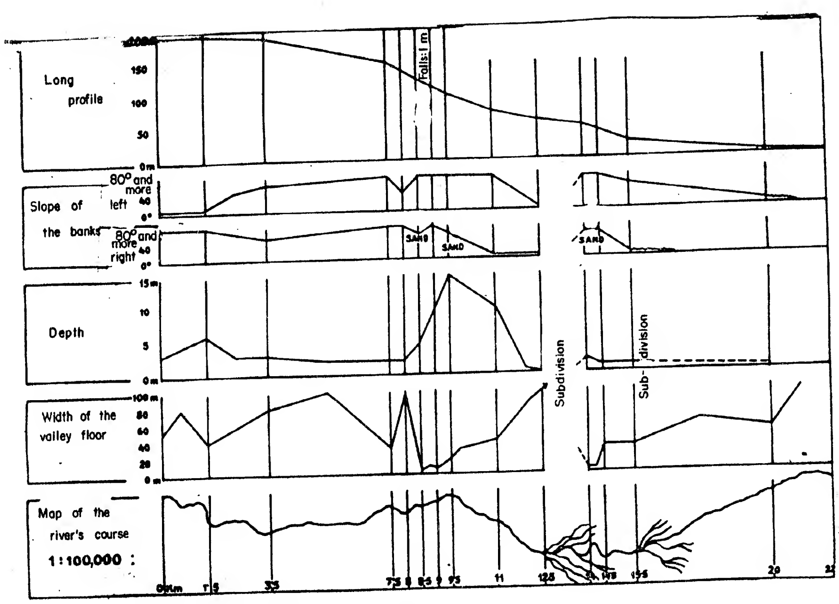


Sketch 11. Longitudinal profile of the route from the gateway of the Lut to the Salt Slab Polygon Kavir



Sketch 12. Profile from the Right Cut Bank of the Khushk-Rud.

The extremely hard salt horizon 20 to 50 cm under the surface is to be found in many places in the Lut. Here, as in other arid regions, the rock material is cemented by salt solutions which rise under capillary attraction and crystallize near the surface.

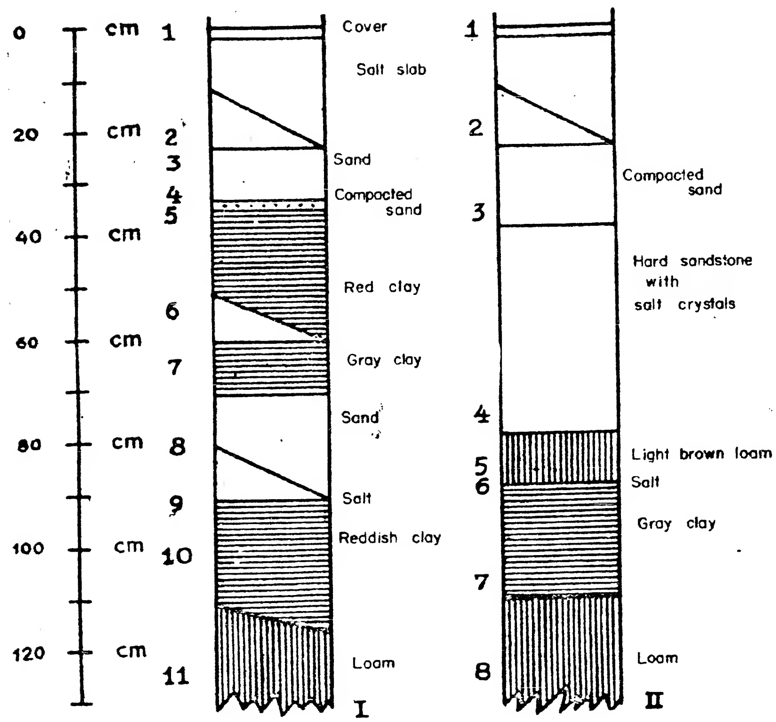


Sketch 13. Graphic form analysis of the Tabasan Valley

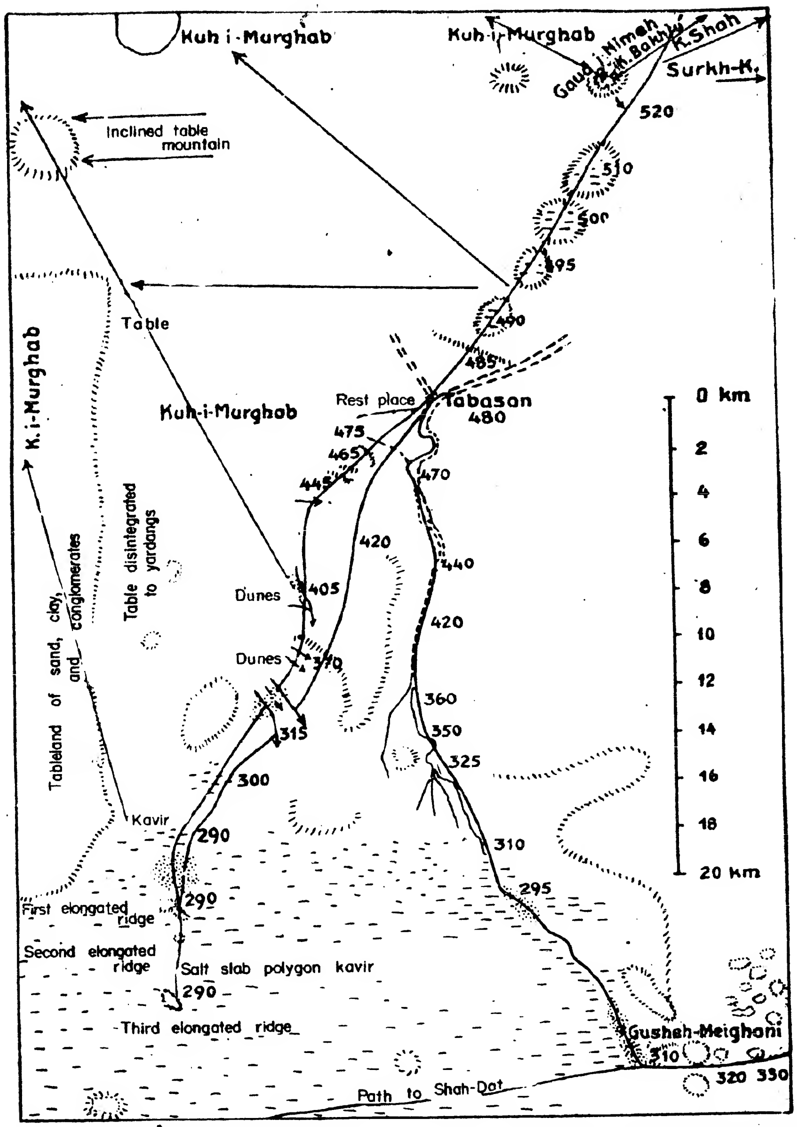
TABLE FOR THE GRAPHIC FORM ANALYSIS
[To accompany Sketch 13]

Route Point	Km from Tabasan	Width of the Valley Floor (m)	Type of Valley Floor (S=sand; G=gravel)	Maximum Depth (m)	Banks* Right	Banks* Left	Elevation Above Heart of Desert (m)	Remarks
8	0	50 + 80	Smooth; S, G	3	4	-1	195	Widening left; sand beds right
9	1.5	40 + 60	Smooth; S, G	6-3	4	1-2	187	G smaller than on the banks
10	3.5	80 -100	Ripple marks; rills; S, G	2-3	3	3	181	Salt efflorescences left
11a	7.5	30	Uneven; S, G	2	4	4	150	Bend
11b	8.0	100	Ripple marks; rills; S	2	4	2	-	Rills join
12	8.5	5-8	Channel; G, S	4-8	3	4	125	Corrugations; sand beds; drift sand
13	9.0	5-10	Channel; G, S	10	Blown over with sand 4	4	112 1 m falls	Same
14a	9.5	20-30	Channel; G, S	15	3	4	100 small falls	-
14b	11.0	40-80	Rills; S, G	10-20	Blown over with sand -1	4	75 small falls	Diagonal corrugations; steep left bank
15	12.5	100 and more	Sub-division	1	1	1	62	Branches right and left
16a	14.0	4	Channel; meanders; S	2	3	4	50	Main branch
16b	14.5	30	Rills; G, S	2	3 Overhanging	4	-	Corrugations
17	15.5	30-60	Sub-division; G, S	1	1	1	25	Corrugations; branches; right and left
18	20.0	50-100	S, G	0.5	-1	-1	12	Polygon kavir in places
19	22.0	-	Polygon kavir, strewn with gravel at first					

* -1 = no erosion rim; 1 = gentle, about 10 - 20°; 2 = fairly steep, about 20 - 45°; 3 = steep, about 45 - 80°; 4 = very steep, over 80°.



Sketch 14. Profiles from excavations in the Salt Slab Polygon Kavir.



Sketch 15. Route Map: from the Gaud-i-Nimeh to the third of the elongated ridges.

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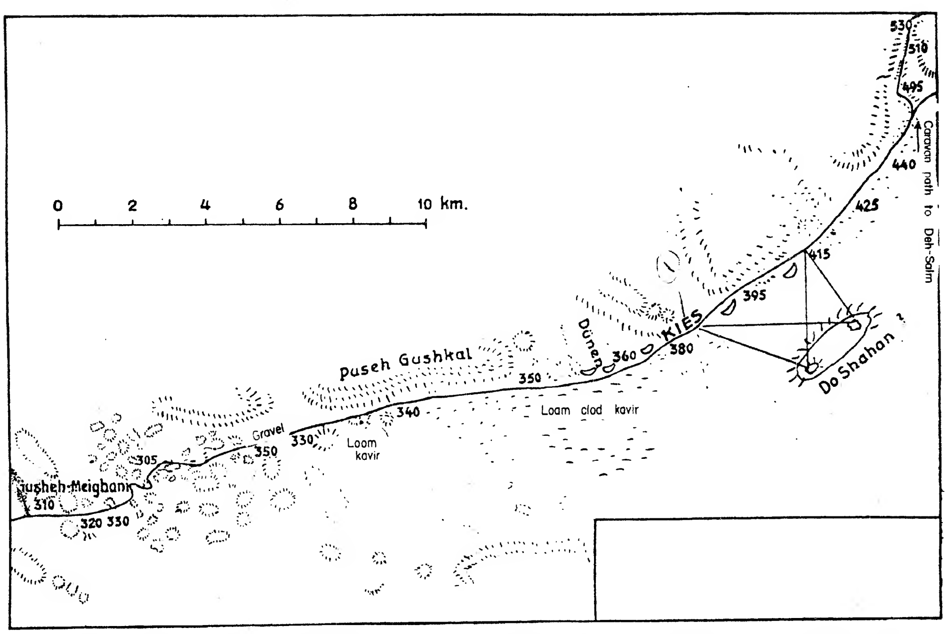

Sketch 16. Route from the northeast end of the Slab Polygon Kavir to the climb to the higher level.

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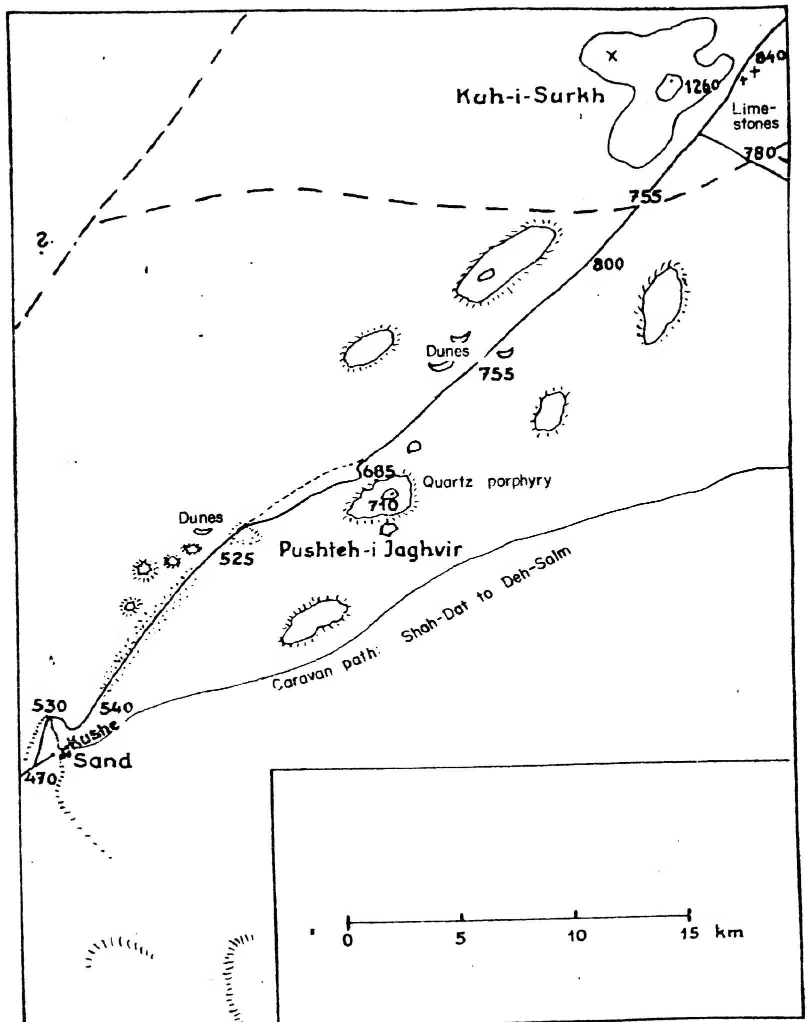
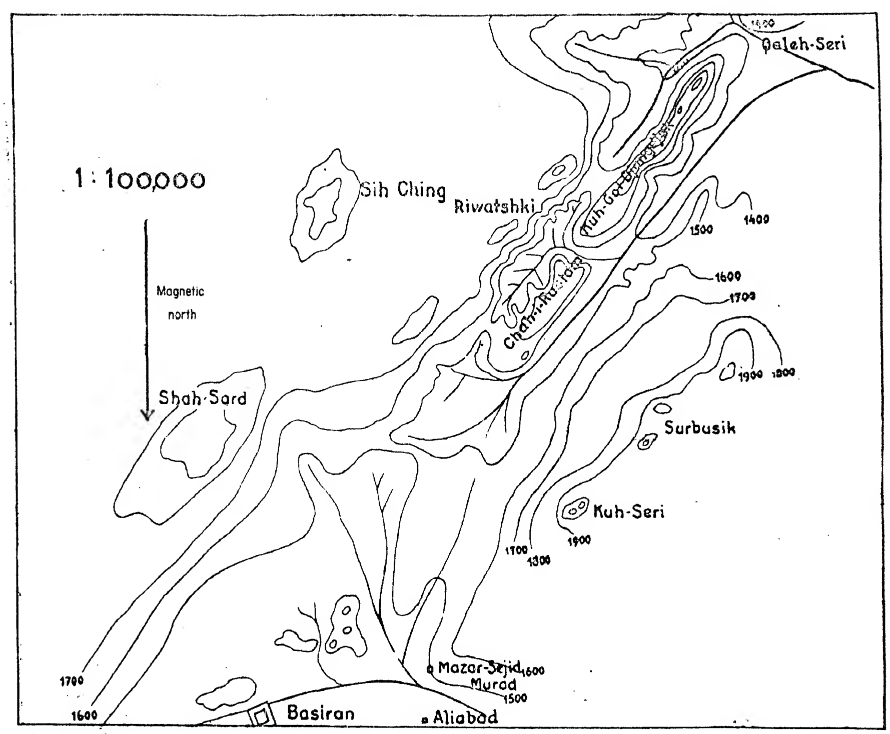
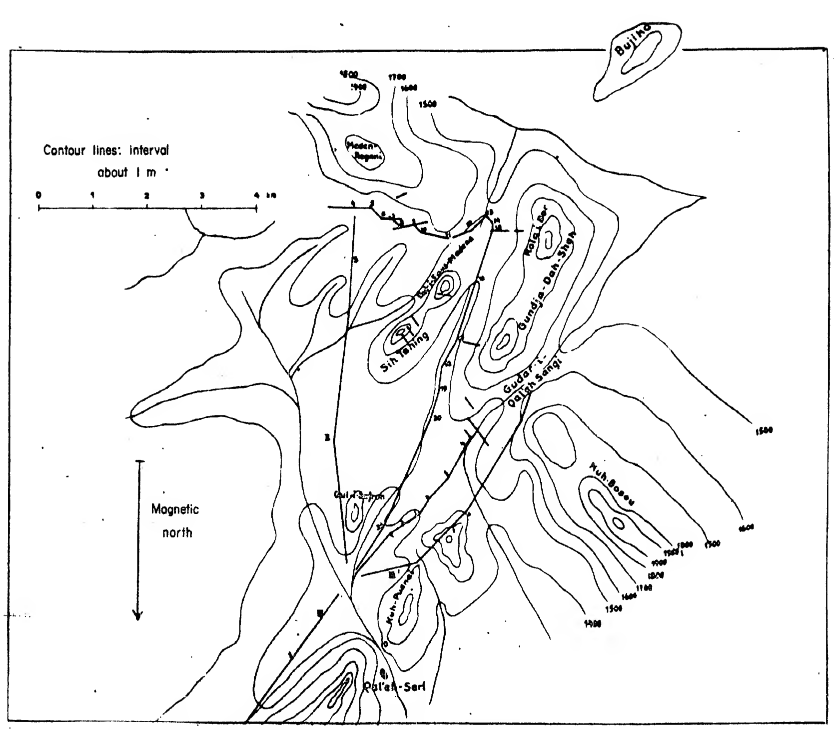


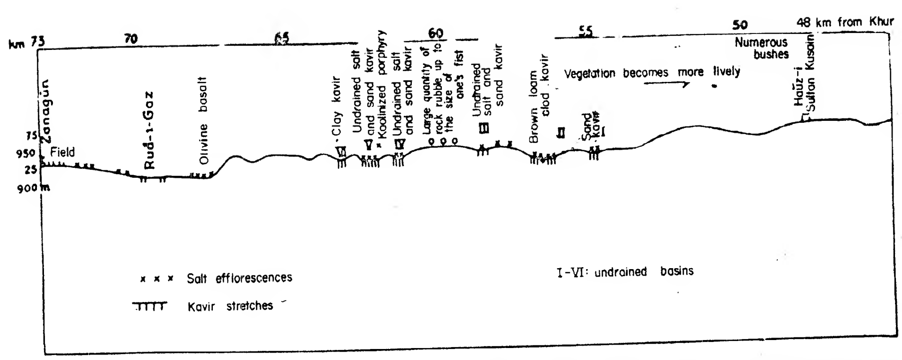
Sketch 17. Route map of the Lut between the Kuh-i-Surkh and Kushe.



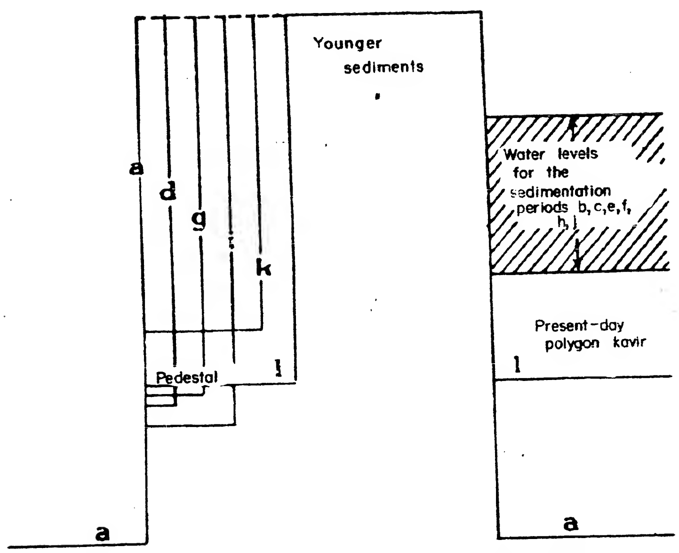
Sketch 18. Route Map: Basiran to Qal'eh-Seri.



Sketch 19. Sketch Map of the region of Qal'eh-Seri



Sketch 20. Elevation Profile of the Stretch between Zanagun and the Hauz-i-Sultan Hasain on the Route to Khur (exaggeration of the vertical scale: X 20)



Sketch 21. Schematic representation of the development of sedimentation and denudation.

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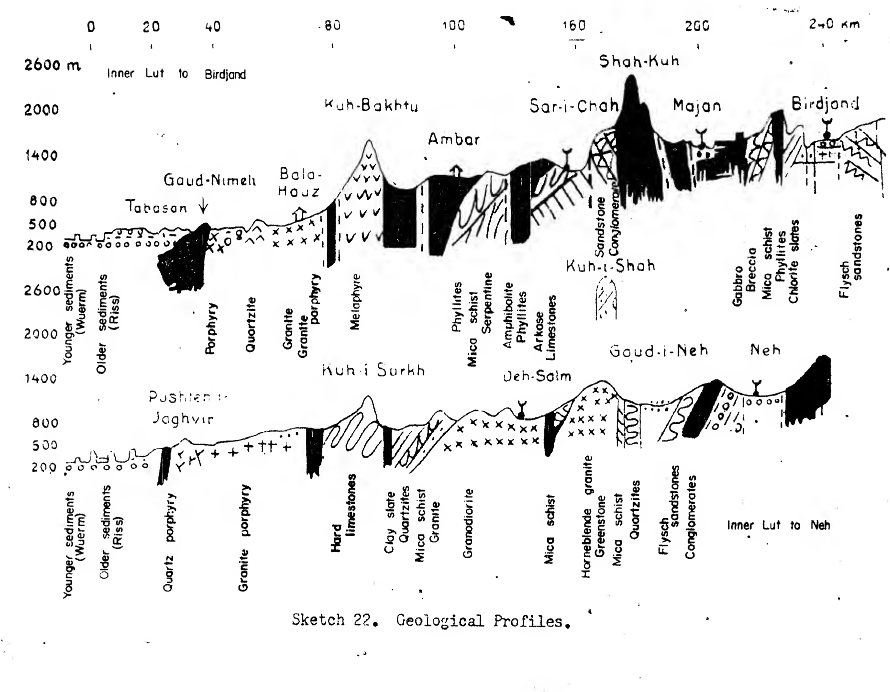

Sketch 22. Geological Profiles.